SCIENCE TEXT-BOOKS

PRACTICAL ZOÖLOGY

COLTON

D. C. HEATH & Co.

CONTENTS.

AN

ELEMENTARY COURSE

IN

PRACTICAL ZOÖLOGY.

BY

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PREFACE.

In the entire absence of any handbook of zoölogy adapted to the grade of work in which he was engaged, the author began to draw up, for use in his own classes, simple guides to the study of a few common animals. After repeated tests in the class-room, and under the advice of a number of eminent teachers of the subject, it was decided to put the work into print.

The author takes this opportunity to thank those who have so heartily aided him in this undertaking.

Prof. Alpheus Hyatt, of the Boston Society of Natural History, has generously aided in preparing the book for publication.

Pres. D. S. Jordan, of Indiana University, has read most of the manuscript and proof-sheets, and has given many valuable suggestions.

Especial thanks are due also to H. Garman, Assistant-Professor of Zoölogy, University of Illinois, for corrections and suggestions on the entire manuscript and on the proofs.

Mr. B. H. Van Vleck, Assistant, Boston Society of Natural History, revised the manuscript on Echinoderms, Cœlenterates, and Sponges.

As the proof-sheets appeared, from time to time, they were critically read by Prof. N. S. Shaler, Harvard

University; Mr. J. Y. Bergen, Jr., Peabody, Mass.; Prof. R. E. Call, Missouri Agricultural College and University, Columbia, Mo.; Mr. E. P. Jackson, Boston Latin School; Prof. L. M. Underwood, Syracuse University, Syracuse, N.Y., and other well-known teachers. In the preparation of the book, free use has been made of the works cited in the text.

To aid in the study of the marine animals, arrangement has been made by which schools may be supplied with sets of material put up at the Seaside Laboratory, Annisquam, Mass. A list of these specimens will be found at the end of this book. They may be obtained of Mr. B. H. Van Vleck, Assistant, Boston Society of Natural History.

It is believed that with the assistance above acknowledged, the book will be found fairly free from errors; but, for any mistakes it may contain, the author alone should be held responsible.

The author believes that he has encouraged only the most merciful methods of handling live animals, and he would strongly urge all teachers not to do anything that might lead to cruelty to animals.

The only way to know animals, is to see and to handle them; and it is sincerely hoped that the day is near when knowing an animal's name will not pass for knowing the animal itself. If this little book should do somewhat toward the improvement of methods of teaching zoölogy, the author will feel that he has not labored in vain.

OTTAWA, ILL., Aug. 20, 1886.

INTRODUCTION.

THIS work is designed to aid the student in getting a clear idea of the animal kingdom, as a whole, by the careful study of a few typical animals.

Most of the animals selected are abundant in the interior States, and are easily collected.

These guides to the study of animals have been used several years, and put into the hands of each pupil, together with the specimens themselves.

The general plan of study is as follows: —

1. Directions are given for collecting and preserving the specimens.
2. The live animal is studied.
3. The external features are noted.
4. The animal is dissected.
5. The development of a few forms is traced.
6. After studying each animal, its relations to other animals are considered (classification).

The aim is, not to describe for the student, thus robbing him of the opportunity to develop his own powers of description, but to name the parts, telling merely enough to enable him to recognize and apply the names to them. This makes a real connection between words and things.

It is thought best for the student to make many of the definitions for himself. A definition, thought out by the

student himself, imperfect though it be, is of more value to him than a perfect definition learned from a book, which often appeals to mere memory. Definitions made in the way these pages require are good as far as they go: they should be corrected and supplemented by the instructor. It develops a boy more to earn a dime than to receive a dollar as a gift.

If the main object of this study is the mere acquisition of facts, full descriptions of most animals can be elsewhere obtained; but if the more important part in education is to lead the pupil to see and think for himself, then some such method as this should be used.

The underlying object in all our teaching is to make seeing, thinking, self-reliant, honest men and women. All branches of natural science, rightly pursued, are powerful means to this end.

"The feeling is becoming general that practice must be united with theory, in the education of young men, or the best results of education are lost. The powers and faculties, instead of being educated — drawn out and developed — are crushed under a mass of merely memorized facts and theory, and at the end of his educational course the young man finds himself unfitted for the work of the actual world, and has to unlearn, and learn again, before he can find the path to success.

"This feeling has resulted, in Germany, in the object-teaching of Frœbel; in Russia, in that celebrated system wherein practical work is united with the theoretical teaching, which already shows such important results; and in the United States, in the building of workshops and laboratories for the use of students in our higher schools and colleges."

The order in which the animals are presented has been determined by the following circumstances : —

The work in zoölogy has usually begun with the fall term. At this time insects are abundant, and *many kinds* may be easily collected; they therefore serve well to show how animals are classified. The leading principles of classification having been taken up in connection with insects, no other group is so fully dwelt upon.

By beginning at this time, the transformations of the butterfly may be followed through during the school year.

Insects are *attractive ;* from insects the student passes on to forms which, if taken up at first, would perhaps be distasteful to him. Thus it is found that the most squeamish pupils gradually become accustomed to the free handling of all forms of animals. The subject need not be presented in its least attractive form at first.

After devoting considerable time to insects, the student takes up the crayfish, earthworm, clam, snail, a few protozoans, a snake, a fish, a frog, a bird, and a mammal. This order of study has been found convenient, but the order is not a matter of great importance; the general principle should be, — study what comes to hand. "He is a good naturalist who knows his own parish thoroughly."

Special stress is laid on devising cheap appliances for collecting, preserving, and dissecting specimens.

These directions make no pretence of being complete dissecting guides, but have been adapted to the ability of ordinary pupils in the second year of a high school course, and to the time allowed this study.

TO THE SCHOOL BOARD.

For practical work in natural history the teacher needs a room in which is but the one class with which he is at work. This room should be provided with plain tables having drawers in which pupils may keep dissecting instruments, drawing materials, and specimens for study.

This work is greatly aided by having a water supply in the room where the work is done ; this is not only a very great convenience to the teacher, but the pupils are much more ready to take hold of slimy specimens and the work of dissecting, if they can wash their hands conveniently before passing to recitation or study room.

The teacher cannot do justice to this kind of work if he has recitation after recitation continuously through the day; time is needed in which to prepare dissections which are too difficult for the students to make, or for which they have not the time; to arrange the material so as to save time when the class has assembled, as well as to clear away afterward, and be in readiness for another class. The following has proved a good arrangement: in a school having three recitation periods in each half day the middle period of each half day is "vacant," *i.e.*, no class comes to the teacher of science at this hour; but this time has been very far from vacant.

It is much better to buy several low-priced microscopes than one expensive one.

TO THE TEACHER.

Do not set out with the intention of finishing this book in a given time; zoölogy is the study of *animals;* study animals as long as the time allows, trying to learn as much

as possible from a few typical forms; this will give a better view of the animal kingdom than reading many books concerning many animals.

Take the study of the grasshopper as an example. The first day put the specimens into the hands of the pupil, or, better, have him bring his own specimens; with the aid of his dissecting guide he studies the whole hour; the teacher goes about, helping those who need, giving directions as to use of instruments, etc. Notes and drawings should be made in a scratch-book; many a pupil says, "I cannot draw"; ask him to do his best; praise his work if you can; suggest how he can do better. The next day question the pupils on what they have seen; perhaps half the hour, or less, will serve to bring out what has been discovered on the preceding day. As soon as what has been seen is brought out, go on with the study of the specimens.

After questioning on all the work, call for carefully made drawings and descriptions in a permanent note-book. A systematic arrangement of these notes should be insisted on; but each pupil should be allowed to follow his own plan as far as possible: encourage individuality.

The name of the study, and of the pupil, should be on a white card, or paper, pasted on the outside of the cover. An index of the notes should be made, as the work progresses, on the inside of the back cover.

If a rubber band be slipped over the front cover and the pages already examined, much time will be saved in looking over the books, as they are handed in from time to time.

Urge the pupils to do as much as they will to procure specimens for class work, but have in reserve a good supply of material. The school should have a supply of alco-

hol. One boy may live near a creek where he can easily get crayfishes or clams for the whole class; another may happen on a lot of beetles. At the beginning of the work ask them to carry boxes or bottles, and be on the lookout for specimens; in this way they will learn more, and lighten your work. But do not neglect class excursions; go out after school with as many as will accompany you; have picnics on Saturdays with them.

Let each pupil be required to make a small collection of insects; it is well to urge each pupil to select some order or family of insects for special study. Written or oral reports of such observations are helpful, and serve to vary the work. If there be time, let the pupils select some of the following subjects for investigation and reading: the chinch bug, silk-worm, bark louse, army worm, cut-worm, potato worm, mosquito, gall fly, ichneumon fly, Hessian fly, cicada, locust, cochineal, May fly, June beetle, cockroach, firefly, daddy-long-legs, plant louse, bed-bug, louse, tick, jigger, flea, wasp, honey bee, ant, cabbage worm. Compare these with the types studied. Ask the questions: What insects are injurious to man? How can we get rid of them? What insects are beneficial? How can we best propagate them?

Make blow-pipes for the students by drawing glass tubes to a fine point, rounding the sharp edges in the flame, so they will not cut. Tip with sealing wax a lot of bristles, both black and white, for probing. Have a good supply of cigar-boxes. At the beginning of the oyster season ask a restaurant keeper to open oyster cans on the side and save them for you; use these for dissecting pans, as described under "the crayfish."

It may be better for the teacher to make the dissection

of the snake, turtle, and a few of the forms that cannot usually be obtained in sufficient numbers to supply the whole class, and to make some of the finer points clearer, especially when the time is short; but each pupil should do most of this work independently, with occasional suggestions from his teacher.

If the school does not furnish a microscope, get one yourself.

TO THE STUDENT.

For this work you need:—

1. A small pair of forceps.
2. A small pair of scissors.
3. A knife.
4. Two dissecting needles, made by thrusting the eye end of a large needle into the end of a pen-holder.
5. A hard pencil for drawing.
6. A good pair of eyes.
   Keep these all sharp, especially number 6.
7. A lens, such as the three-legged lens, or the linen-tester.
8. A scratch-book in which to take notes while studying the specimens. Keep this and number 5 in the drawer of your work table.
9. A note-book, in which descriptions of the animals studied should be carefully written in ink.
10. A bottle of mucilage (for every four students).
11. A quart fruit-jar.

In drawing, first trace the outlines; then if these seem correct when carefully compared with the object, make the lines heavier. Avoid shading. See Morse's "First Book

of Zoölogy" for models of simple drawings. Draw no line that does not correspond, as closely as you can make it correspond, to something in the object before you. Look closely at the object before you put pencil to paper.

In dissecting, follow the directions minutely; they are made with care, so as to save time, labor, and material.

COLLECTING INSECTS.

Make an insect net as follows: get a light wooden handle four feet long, and the same length of stout brass wire; bend the wire into a ring a foot in diameter, cut a notch in the end of the handle, cross the ends of the wire in the notch, and bend the ends so they will run close along the handle for six inches; half an inch from the end of the wire, bend it at a right angle, and drive into the handle; then wrap tightly with fine wire.

The ring may be made of a barrel-hoop by steaming it till flexible, and bending along the handle and nailing firmly. Sew to this ring a bag of thin muslin, twenty inches deep.

The net is used for capturing strong flying insects, such as butterflies and dragon-flies, and for sweeping over the tops of bushes and grass. When one of the strong fliers is taken by the net, the handle should be instantly twisted to throw the bag over the ring and prevent escape.

Butterflies may be killed by pinching the thorax between the thumb and finger; fold a two-inch square of paper cornerwise, put the butterfly in the fold, and again fold the edges and corners. A better method of killing butterflies is as follows: Pack cotton two inches deep in the bottom of a Mason fruit-jar; trim wire gauze to fit closely

and press it down on the cotton; saturate, or nearly so, the cotton with chloroform just before starting out to collect.

For killing most insects use a cyanide bottle, prepared thus: get a wide-mouthed bottle with a glass stopper, or tight cork; place in it two or three pieces, as large as caramels, of cyanide of potassium; this is a very violent poison, even its fumes being deadly; it should be handled as little as possible, — pick the pieces up in paper, — and should be labeled "*Poison*," and kept away from children and ignorant persons. Mix plaster of Paris and water to a thin paste, and pour over the cyanide, covering the lumps half an inch deep. Let the bottle stand uncorked a day to dry; the plaster hardens, but, being porous, allows the poisonous fumes to rise; after drying a day it should be kept tightly corked.

When an insect is in the net, the bottle may be uncorked, pushed into the net and over the insect, and the insect pushed into the bottle by the cork, thus avoiding stings, as well as injury to the insect.

Hard insects, as beetles, bugs, and grasshoppers, may be put at once into alcohol. If not used soon, they will thus be better kept.

Many insects, such as bees and beetles, may be taken from flowers by quickly pushing them into the bottle with the stopper.

An umbrella is very useful in collecting certain forms of insects. Hold the umbrella spread and inverted under the branches of trees and shrubs, and beat the branches with a stick, or jerk with the handle, if it has a hook.

A lamp, by an open window, has often been found too

good a means of attracting insects. Some of the most beautiful moths fly only at night.

Look for beetles under logs, boards, and under the bark of old logs and stumps. Look in ponds for insects and their larvæ. Treeless meadows and deep forests are not as good places for insects as gardens, the edges of woods, and the banks of streams and ponds. Collect cocoons and larvæ, as well as caterpillars, and keep them to see what they become. It is well to carry several small boxes in which to put such specimens, and insects that have been killed in the cyanide bottle, that they may not become bruised.

MOUNTING INSECTS.

For mounting insects get shallow cigar-boxes. Special pins, called insect pins, are made for this work, but common pins will serve. In the bottom of the box tack small pieces of cork, made by slicing an ordinary cork parallel to its ends. Have the insects about two-thirds of the way up the pin. Pin beetles through the right wing cover. Pin butterflies with the wings spread, and pin through the side of the body to show the position when at rest. If the insect has dried, it may be softened by wrapping in a wet cloth, in the case of hard insects as beetles and grasshoppers; for softening butterflies, put a wad of soaked paper into a fruit jar, cover this with dry paper, and put in the butterflies still in their papers. Having softened the insect in this way, it may be pinned to a piece of cork or a pin cushion, and the wings having been stretched, they may be pinned in this position, and so kept till dry. For holding the wings in place cut small triangles of thick paper, thrust the pins through these triangular papers; and

setting the pin so that the pin itself shall keep the wing from moving forward or backward, so regulate the height of the three-cornered papers that the wing may be held at the proper height. A setting board may be made as follows: two boards, sloping toward each other, and half an inch apart, are fastened to a wide board as a base. The channel, or groove, between them should be half an inch deep, and a strip of cork fastened to the bottom for holding the pins. Pin through the body of the insect, and, the body extending along the groove, let the wings rest on the smooth, upward-sloping sides. Place the wings as desired, lay narrow strips of paper over them and pin the strips down. As the wings extend slightly upward, and dry in this position, they will be less likely to droop after permanent mounting. Draw the wings of butterflies forward, in setting, till the hind margins of the fore wings form a straight line. Let this rule apply to any spread insect. Pin a beetle and a grasshopper side by side to show the difference in the position of the wings, both folded and expanded, and the different manner of folding the wings. The name of the insect, date, and place of capture, should be written on a small slip of paper and kept on the pin below the insect.

In each box of insects place a piece of camphor to protect from injurious insects.

BREEDING CAGES.

Take a starch box or chalk box with a sliding cover; cut off three inches from one end of the cover; slide this short piece of cover into the farther end; set the box on this end and put in three inches of soil; insert a sliding glass cover which projects a little above the top of the

box. Put in this box some larva, say a potato worm; feed it daily with the leaves on which it was found feeding; keep the soil moist, and, if no change takes place before cold weather, remove to a cellar and keep till spring. Any good-sized glass jar will serve as a breeding cage, as a candy jar, fruit jar, or battery jar, with a piece of tin laid on as a cover. A jelly glass makes an excellent breeding case for eggs and young larvæ.

PRACTICAL ZOÖLOGY.

THE GRASSHOPPER.

THE PARTS OF THE BODY.

1. The foremost, or **anterior,** part is the **head.**
2. The middle part is the **thorax.**
3. The hinder, or **posterior,** ringed part is the **abdomen.**

THE HEAD.

1. Notice its shape and mode of attachment to the thorax.
2. Two slender projections, the feelers, or **antennæ.** Observe how and where they are attached to the head. Use a lens to count the parts, or **segments,** of which each antenna is composed.
3. Note the situation and shape of the eyes. Examine one of the eyes under a microscope, using a one-inch objective; make a drawing of what you see. These eyes are **compound,** and each of the parts is called a **facet.**
4. Just in front of the compound eyes look for a pair of simple eyes, the **ocelli.** Find a third ocellus on the head, using a lens if necessary.
5. At the lower part of the front of the head is a movable flap, the upper lip, or **labrum;** raise it with the

dissecting needle. Observe how it is hinged; cut or break it off.

6. This lays bare the true jaws, or **mandibles.** Examine their black, toothed tips with a lens; find, by prying, how they move. Study their action in the live grasshopper, raising the labrum. Study carefully the way in which they move, and how they are hinged; then remove with the forceps, and again examine thoroughly.
7. Back of and between the mandibles is the brown **tongue.**
8. Turn now to the back of the lower part of the head; pry back the lower lip, **labium**; carefully remove it.
9. Attached to the base of the labium is a pair of short, jointed appendages, the **labial palpi.** What is the relation between the tongue and the labium?
10. If the above-named parts have been carefully removed, there will remain one pair of appendages, smaller jaws, called the **maxillæ.** Make out that each maxilla consists of three parts: —

    a. An outer, jointed part, the **maxillary palpus.**
    b. A spoon-shaped piece covering *c.*
    c. The brown, in-curved maxilla proper. Examine with a lens, then with forceps remove the whole maxilla, being sure to get the basal part.

11. Cut the head off a fresh specimen; lay it on the table and make a careful drawing of the face, naming all the parts.
12. Draw the head as seen from the side.

THE THORAX.

1. The wide collar, or cape, back of the head is the **prothorax**; make a drawing of it as seen from the side.

2. The remainder of the thorax is formed by the union of two parts, each bearing a pair of legs, the part to which the middle pair of legs is attached being the **mesothorax,** the hinder legs arising from the **metathorax.** Look for the line separating these two parts of the thorax.
3. Look just above the second pair of legs for a narrow opening, guarded by a pair of lips, which, in the live grasshopper, keep separating and coming together; this is a breathing pore, or **spiracle.** Look for another spiracle on the soft skin under the posterior edge of the prothorax on each side.
4. Carefully compare the prothorax, mesothorax, and metathorax.

THE WINGS.

1. Notice the position of the outer wings, and their mode of overlapping.
2. With the forceps seize one of the outer wings by its lower edge, near the anterior end, and draw it horizontally forward, till it makes a right angle with the body, and pin in this position. Seize the inner wing by its lower edge near the posterior end, and pull forward to its fullest extent, observing how it is folded; pin this wing as expanded, and make a drawing of both wings as thus seen. Cut a piece of paper the same size and shape as the inner wing, and fold it as the inner wing is folded.
3. The framework of the wings is composed of **veins.**
4. Compare the inner and outer wings in: —

   a. Size.

   b. Shape.

c. Color.
d. Texture.
e. Position, both when at rest and in motion.
f. Use.

THE LEGS.

1. Note their number, arrangement, and mode of attachment.
2. Study carefully one of the hind legs.

   a. A short segment near the body, the **coxa.**
   b. The big segment is the **femur.**
   c. The slender segment is the **tibia.**
   d. The remainder is the foot, or **tarsus;** count its segments, and examine thoroughly, using a lens. Remove a hind leg, and make a drawing showing all these parts.
   e. Examine the joint between the femur and tibia, moving the parts back and forth. Note, also, how these parts fit together when the leg is drawn up.
   f. In how many ways does the grasshopper travel? In what order are the legs moved in crawling?
   g. Grasshoppers make a shrill sound (stridulation) by rubbing the inner surfaces of the hind legs against the outer wings.
   h. In what different ways does the grasshopper keep from slipping when it jumps? Remove the legs and wings; make drawings of the thorax as seen from the side, from above, and from below.

THE ABDOMEN.

1. Count the abdominal rings.
2. Observe two grooves running along the under surface of the abdomen. The under part of the abdomen, included between these grooves, is the **sternum,** the side of the abdomen is called the **pleurum,** and the upper part is the **tergum;** the corresponding parts of each separate ring are the **sternite, pleurite,** and **tergite.**
3. Just above the groove which separates the sternum from the pleurum is a row of small holes, the breathing pores, or **spiracles;** count them.
4. In a live specimen, watch the movements of breathing. All insects breathe by means of a complicated system of air tubes, the **tracheæ,** which branch from the spiracles throughout the body. Can the grasshopper be drowned by holding its head under water? Connected with the air tubes, in grasshoppers and other strong flying insects, as bees and flies, are large air sacs, which fill with air, and are said to aid, like little balloons, in keeping the insect in the air. By carefully cutting away the roof of the abdomen, these air sacs may be seen, marked by their white walls; the white air tubes, or tracheæ, may also be readily seen.
5. Under the bases of the wings, on the first abdominal ring, is a pair of thin, shiny, oval membranes, the **tympana,** or ear drums. The inner surface of each tympanum is connected with a nerve; but several investigators have denied the auditory nature of this apparatus.
6. The abdomen of the female ends in four points; in

laying the egg these points are first pressed together, then thrust into the ground, and then separated; this process is repeated till a hole is made, sometimes as deep as the abdomen is long, at the bottom of which the eggs are deposited, passing out between the four points of these egg guides, which together are called the **ovipositor**; compare the inner and outer surfaces of these egg guides. The males are smaller than the females. Draw the abdomens, as seen from the side, of both the male and the female. Take now an entire specimen and draw a side view of it.

INTERNAL STRUCTURE OF THE GRASSHOPPER.

This work would better be done after the student has dissected the crayfish. Dissect under water with the dissecting pan as described under the "crayfish."

1. Get a large female grasshopper, freshly killed. Cut off the wings, and place the specimen, back uppermost, in the dissecting pan; pin the hindermost ring of the abdomen firmly to the bottom of the dissecting pan; turn each hind leg outward and pin down. With sharp, fine-pointed scissors, cut through each side of the roof of the next to the last abdominal ring; lift, with the forceps, the cover of this ring; continue the cut forward, on each side of the abdomen, pulling the tergum upward and forward as it is loosened. Thus carefully unroof the whole abdomen.
2. The heart is a delicate tube, running along just under the tergum, and probably was torn away with the tergum.
3. On each side there should now be seen a row of air sacs, with their white air tubes.

4. In the anterior part of the abdomen a mass of yellow eggs is usually to be found; this mass may be easily separated into two parts, right and left, from each of which a tube, **oviduct,** leads to an opening between the parts of the ovipositor.
5. Under the eggs is the dark **intestine,** running lengthwise.
6. Remove the roof of the thorax; more air sacs should be found here. In the upper part of the thorax are the white **muscles** which move the wings. Removing these muscles exposes more of the digestive tube; as the food is swallowed, it passes upward in a brown tube, which soon turns backward into the thorax; in the prothorax, the enlargement is the **crop,** in which is produced the dark liquid which the grasshopper ejects from the mouth when held captive. The crop may be removed, washed, split open and examined under the microscope with a half-inch objective to show the rows of hooked teeth with which it is provided. A little further back the digestive tube is surrounded by a set of double cone-shape pouches, which extend parallel with the main channel of the digestive tube. These are the **gastric cæca.** Behind them is the stomach, followed by the intestine. The products of digestion pass through the coatings of the digestive canal, and mingle with the currents of blood which pass along the ventral and lateral parts of the body.
7. The colorless blood enters the heart through holes along its sides; blood is sent from the heart into the veins of the wings. These veins are hollow tubes, and though they convey blood, are very different from the veins in our bodies. Air tubes run along

the centre of the larger veins, and give air to the blood as it flows.

8. The nervous system of the grasshopper consists mainly of a white cord extending along the floor of the whole body cavity. In most of the abdominal rings the nerve cord has enlargements called **ganglia,** from which nerves branch to the surrounding parts.

THE DEVELOPMENT OF THE GRASSHOPPER.

The egg hatches out a little grasshopper, at first without wings. As it grows, it sheds its skin (moults) several times. In moulting, the skin splits along the back of the head and thorax, and the insect works its way out. At first the newly hatched insect is very soft; the writer has seen a grasshopper bend its tibia double in the effort of pulling out of the old skin; but the tibia soon straightened and hardened, showing no signs of injury.

For descriptions of the grasshopper, see Packard's "Zoölogy," Packard's "Guide to the Study of Insects," Brooks' "Handbook of Invertebrate Zoölogy," "The Rocky Mountain Locust," in First Annual Report of U.S. Entomological Commission, 1877 (issued 1878), Comstock's "Guide to Practical Work in Elementary Entomology."

GRASSHOPPER CARD.

Take a card six inches by four. Make a faint mark lengthwise in the middle to aid in placing the parts symmetrically. Separate the parts of the grasshopper, and paste them on the card in their proper order. Before beginning, plan the whole arrangement. First, cut off the head; leaving a central place for the head, remove the mouth parts, pasting each to the card as it is removed.

In separating the parts use the forceps, being careful to get hold of the very base of each piece; then, holding each part with the forceps, dip the side that is to go next to the paper into the mucilage, and carefully place just where it is to stay. This method avoids smearing the card. Avoid getting too much mucilage. The mouth parts should surround the head; the wings should be opposite the parts to which they were attached, as also the legs. The legs should be separated to show all the segments; the thorax should be separated into its parts, but the abdomen would better be kept entire. As the parts become very brittle when dry, it is well, if the card is to be kept, to make a little bridge of a strip of paper, on which to string the rings of the thorax and abdomen. The soft parts should, of course, be removed.

THE CRICKET.

1. In what are the cricket and grasshopper alike?
2. In what respects do they differ?
3. The female cricket has a long, slender ovipositor. Compare its parts with the parts of the grasshopper's ovipositor, picking them apart with a dissecting needle. Use a lens.
4. A pair of tapering, jointed projections from the abdomen are the **stylets.**
5. Compare the wings of the male and female. Look on the under surface of the outer wings of the male for a vein, running crosswise, near the anterior end, which has on it a row of teeth. By rubbing this **file** on the

veins of the other wing, the cricket makes its chirping noise. Watch crickets to see how the wings are managed during this process.

6. With a lens look for the so-called hearing organ on the tibia of the fore leg.
7. Make a drawing showing all that can be seen from above (dorsal view), and naming all the parts shown.

Grasshoppers and crickets both belong to the order of insects called **Orthoptera,** or straight-winged insects.

THE BUMBLE BEE.

1. Find three ocelli on the top of the head. How are they arranged?
2. Describe the antennæ.
3. The mouth parts: —

   a. A pair of true jaws.
   b. The long, hairy tongue.
   c. Above the tongue the two blades of the maxillæ.
   d. Below the tongue the thin, narrow labial palpi.

The last three form a proboscis; pick the parts asunder, and make a drawing of the front of the head, showing all these parts.

4. How does the bee take its food? Is the honey stored by the bee the same as when taken from the flower?
5. Compare the segments of the legs with those of the grasshopper. How does the bee get pollen? What does the bee do with the pollen?

6. Examine the wings; compare the front and hind wings.
7. Get a bumble bees' nest; examine the contents of the cells, and note the different stages of development of the young bees.
8. The sting is a modified form of ovipositor. Near its base are poison glands, and a sac for storing the poison.
9. How do bees compare with other insects in intelligence?
10. Read the account of the habits of bumble bees, and of honey bees, in Packard's "Guide to the Study of Insects."
11. Ants, bees, and wasps belong to the order **Hymenoptera,** or membrane-winged insects.

THE BUTTERFLY.

The large, brown "milkweed butterfly," with dark markings along the veins of the wings, is a good one to study.

1. Notice the position of the eyes, and their relative size.
2. Where are the antennæ attached? Compare with those of the grasshopper.
3. The short projections in front of the head are the labial palpi.
4. Between the palpi is the coiled sucking tube; uncoil and examine it.
5. The wings: —

a. Their shape and their mode of overlapping.

b. The dark, shiny veins; where are they strongest?

c. Scrape some of the scales off a wing; examine under a high power of the microscope, making drawings.

d. Examine a piece of a wing, with the scales on it, to see how they are attached and arranged. Look at a part of the wing where the scales have been removed.

6. Spread the wings of the butterfly, and draw them as seen from above.
7. Examine the legs, and compare their use in this insect and others.
8. Make a drawing of the butterfly as seen when at rest, naming all the parts visible.
9. Compare the colors and markings of the upper and lower surfaces of the wings.
10. Carefully compare a moth and a butterfly.
11. Butterflies and moths belong to the order **Lepidoptera,** or scaly-winged insects.

The orders of insects are divided into **families;** this butterfly belongs to the family **Nymphalidæ.**

Families are divided into **genera;** this butterfly belongs to the genus **Danais.**

Genera are divided into **species;** this species is **archippus.** So this butterfly belongs to the class, Insecta; order, Lepidoptera; family, Nymphalidæ; genus, Danais; species, archippus.

The males are distinguished by an elevated black spot along one of the veins, near the middle of the hind wings.

Where is this butterfly found most abundantly?

Consult French's "Butterflies of the Eastern United States," for finding the names of butterflies.

DEVELOPMENT OF THE CABBAGE BUTTERFLY.

The cabbage butterfly is small, yellowish beneath, paler above, with black tips to the anterior wings. The male has one round, black spot only on each upper wing, while the female has two, and sometimes three.

1. Open the abdomen and look for eggs. They are yellow, oval bodies ribbed lengthwise, with cross markings on the ridges, resembling stunted ears of yellow corn. Look also for these eggs on cabbage leaves, or where these butterflies are seen hovering. Watch the butterflies closely as they light on the cabbage leaves, to see the egg deposited on the leaf; on which side of the leaf are the eggs usually laid? How are they fastened to the leaf? Make a drawing of the egg as found attached to the leaf.
2. Get a chalk box with a sliding cover; substitute a glass cover a little longer than the box. Cut windows in the sides of the box and fasten wire gauze over them. Keep the box on end, so that the door will keep closed, yet may be easily opened. Put into this box a cabbage leaf with eggs on it; examine several times a day. What becomes of the egg? In another box, similarly arranged, put some large cabbage worms; give them fresh leaves every day, and keep the box in a light, well-ventilated room. Watch closely, and keep record of the date of the beginning of the experiment, and note the date of any change; describe carefully all actions and changes in the worms. Make careful drawings of each stage of growth:—

a. The egg.
b. The larva, at different stages of growth; keep one worm in a cage by itself, and make a drawing every third day.
c. The pupa, showing how it is suspended.
d. The perfect butterfly.

3. The cabbage butterfly belongs to the family **Papilionidae,** genus Pieris, species rapæ.

There are several species of the genus Pieris, just as there may be several in one family among us; as in a directory we read: "Smith, Charles," "Smith, Edmund"; so we read: Pieris rapæ; Pieris protodice.

What is the meaning of the word "rapæ"?

For account of the cabbage butterfly, see "Report of the Entomologist" in the "Report of the Commissioner of Agriculture for the year 1870."

Occasionally a larva will fail to go through its proper changes; this is generally caused by some parasite, the most common of which is an ichneumon larva. The adult of some kind of ichneumon fly stings the cabbage worm and lays its eggs in its body; these eggs hatch out as worms and live on the juices and tissues of the cabbage worm, till it dies from exhaustion (though the cabbage worm often lingers, and the parasitic larvæ complete their transformation first), and the parasitic larvæ become pupæ, and hatch out as perfect ichneumon flies.

Look for holes in pupæ which fail to complete their transformation; often holes may be found in them where the ichneumon flies have made their escape. If a pupa blacker than usual be found, put it in a vial, or pill box, and catch the ichneumon flies as they emerge.

THE HOUSE FLY.

THE PARTS OF THE BODY.

1. The **head,** the foremost, or anterior part.
2. The **thorax,** or middle portion.
3. The **abdomen,** the hinder, or posterior part.

THE HEAD.

1. Examine the eyes with a strong lens, and under a low power of the microscope, to discern its parts or facets. Such an eye is said to be compound, and in the fly is composed of about 8000 parts; what shape have the facets?
2. Cut off the head, lay it on a glass slide, and with a one-inch objective examine the short antennæ in front of the head.
3. Look on the top of the head for simple eyes.
4. With a lens examine the under part of the head to see the tongue. How does it move? Remove it and look at it with a one-inch objective. How is it used?

THE THORAX.

1. How many legs are there? To what are they attached? How many segments has each leg?
2. The wings; how many are there? Back of each wing find a short membrane, the winglet. Note the folded portion connecting the wing and the winglet.
3. A little further back are two slender knobs projecting on stalks like pins; these are the **balancers,** and are considered as representing the hinder wings found

in most insects. Note the effect of removing the balancers.

4. The wings describe a figure 8 in flying, and make over 300 revolutions (*i.e.*, go up 300 times and down 300 times) in a second.
5. On each side of the thorax, just back of the head, find a narrow opening with yellow, lip-like border; examine closely with the aid of lens and microscope. It is a breathing pore, or spiracle.

THE ABDOMEN.

Are there spiracles on the abdomen? How many rings has the abdomen? Draw the fly as seen from above, dorsal view.

The house fly lays its eggs about stables; after a day or two the eggs hatch out as little worms, or maggots, which eat voraciously and grow rapidly; in about a week they cease eating, become dry and brown, resemble a seed, and neither move nor grow; from this pupa the fly emerges. The adult fly is short lived, though some live over winter. Watch the development of the egg which the flesh fly lays on meat and dead animals. How many kinds of flies do you know? How do they differ? How does the fly walk on the window pane? Examine the feet. In what order does the fly move its feet in walking? For the study of this point, take a fly that is sluggish from cold, or from partial drowning. Do flies, on the whole, injure man, or benefit him? Flies belong to the order **Diptera,** or two-winged insects. What other insects have but two wings? Read the Muscidæ in Packard's "Guide to the Study of Insects."

THE SQUASH-BUG.

1. Find the sucking tube bent back under the thorax.
2. Are there both simple and compound eyes?
3. What peculiarities of the prothorax?
4. Draw a dorsal view, showing how the wings overlap.
5. Draw the squash-bug's wings out at right angles to the body, and make another drawing showing how the outer wings appear when extended, and how the inner wings are disposed.
6. Draw a ventral view.

Look for eggs. Compare young and old squash-bugs. Squash-bugs belong to the order **Hemiptera,** or half-winged insects. What is the propriety of this name? Insects belonging to this order are the only ones that are properly called "bugs."

See account of the squash-bug in Harris' "Insects Injurious to Vegetation."

THE BEETLE.

1. What are the characters that appear peculiar at first sight?
2. Note the position, shape, and range of vision of the **eyes.**
3. The **antennæ,** their attachment, parts, and mode of extension.
4. A small upper lip, the **labrum.**

5. A pair of strong jaws, the **mandibles,** often very large, and projecting forward as pinchers, or "horns." How do they move?
6. Back of these are two small jaws, the **maxillæ,** bearing a pair of jointed appendages, the **maxillary palpi.**
7. Back of (posterior to) the maxillary palpi is another pair of similar appendages, the **labial palpi.**
8. The part of the body back of the head is the **prothorax.** Why not call it the thorax?
9. Pry up the hard outer wings. How do they meet each other? The outer wings are called the wing covers, or **elytra.** In what direction does the beetle move the elytra in raising them? How are they held during flight? Do they rise vertically?
10. How are the inner wings folded? Compare the inner and outer wings in length and size. Cut a piece of paper of the same shape as the inner wing, and fold it as the inner wing is folded. How does the beetle perform the act of folding the inner wings? Capture live beetles and watch this process.
11. Make a drawing of the back, with the wings closed; another drawing, with the wings fully expanded, as in flight.
12. Count the segments of the legs. Examine each segment closely. Seize the foot of one of the hind legs with the forceps, and pull it about in all directions, to see how many joints the leg has, and what motions are allowed by each joint. The segment nearest to the body is the **coxa.** Then come in order, **trochanter, femur, tibia,** and **tarsus** (foot).
13. What marks the line of division between the thorax and abdomen?

14. Draw a ventral view on a large scale, showing especially the parts of the legs, and the mouth parts.
15. Watch a crawling beetle, to see in what order the legs are moved.
16. What can you tell of the habits of beetles? The different kinds of beetles, and their development? What is a grub? Compare beetles with other insects in strength. The large beetles are good insects for dissecting, to show the internal structure. Beetles belong to the order **Coleoptera,** or sheath-winged insects.

See "Classification of the Coleoptera of North America" by LeConte and Horn.

THE DRAGON-FLY.

1. Compare the shape and relative size of the parts of body with those of other insects. In some dragon-flies the eyes have as many as 12,500 facets each.
2. What kind of mouth parts has the dragon-fly?
3. How does the dragon-fly compare with other insects in power of flight? To what bird should the dragon-fly be compared in its habits?
4. Has the dragon-fly a sting? Is it dangerous to man in any way?
5. Watch the dragon-fly dipping the end of its abdomen into the water to lay its eggs. Compare the ovipositor with that of the grasshopper.
6. The larva of the dragon-fly may be found on the bottoms of ponds and streams, and is very noticeable on account of its wide head and prominent eyes, wide abdomen, and short wings.

7. When the larvæ are ready to transform, they crawl up out of the water, their skins split along the back, and the adult dragon-fly escapes, leaving its dry, empty skin, which may be found clinging to the stems of water plants, projecting logs, or rocks.
8. Draw a dorsal view.
9. The dragon-fly belongs to the order **Neuroptera**, or nerve-winged insects.

REVIEW OF INSECTS.

Take any insect not yet studied, and examine it thoroughly. Write a full description, and make drawings of it. To which of the insects previously studied is this most like? To what order, then, does it probably belong?

Select two pages in your note-book that face each other. On the left-hand page make a list of characters common to all the insects you have studied, numbering the points; on the right-hand page write briefly the characters peculiar to each insect. The first list ought to be a very nearly correct definition of an insect, as far as external features are concerned. The second list should serve as a definition of each of the orders of insects.

All the orders of insects belong to the class **Insecta.**

Write now a list, in vertical series, of the orders of insects studied, with the name of the insect representing that order opposite it, and include all within a brace opposite the word **Insecta.**

Read Hyatt's "Insects" (No. VIII. in Guides for Science-teaching). See also "Standard Natural History," Vol. II., and Saunders' "Insects Injurious to Fruits."

THE SPIDER.

Spiders are best preserved in alcohol, as they shrink in drying.

1. The anterior division of the body is the **cephalo-thorax,** or united head and thorax.
2. The large posterior division is the **abdomen.**
3. How many legs are there? To what are they attached? How many segments are there in each? Examine the feet under a microscope. Make a drawing of one of the feet. Can a spider climb out of a tumbler? Compare it with the beetle in this respect.
4. With a dissecting needle pry apart the mandibles, at the front of the head. Make out the fine, spine-like, curved **poison fang** at the lower end of each mandible.
5. Back of the mandibles find a pair of small jaws, the **maxillæ.**
6. To the maxillæ are attached a pair of jointed appendages, resembling a pair of legs, the **maxillary palpi.**
7. With a lens look for the simple eyes above the jaws. How many are there, and how are they arranged?
8. With a lens examine the **spinnerets** at the posterior end of the abdomen. With a pair of forceps hold a live spider by one leg, and watch the beginning of spinning. Highly magnified, the spinnerets appear as blunt protuberances arranged together in pairs, and capable of being contracted or expanded. These spinnerets are covered with hundreds of jointed hairs, which are perforated and through which the web-forming material issues. This material is fluid, and

somewhat like the white of an egg. Escaping from the body, through hundreds of these openings, the strands of this fluid dry almost instantly, and uniting, form the delicate, yet comparatively strong, thread of the spider. Thus it will be seen that the thread of the spider is composed of hundreds of strands, which may often be separated just as the fibres of a rope may be pulled apart.

9. Besides tracheæ, spiders have a so-called **lung,** composed of several leaves, into which blood flows, and is thus aerated.

Place the description of the spider alongside the list of characters common to insects, and note what features are common to the spider and all the insects; also the points wherein they differ.

Spiders belong to the class **Arachnida.** Is the young spider, when first hatched, like the adult? Study the habits of spiders, and their methods of spinning their webs and capturing insects.

Read Emerton's "Spiders, their Structure and Habits," and the chapters on spiders in Morse's "First Book of Zoölogy," Packard's "Zoölogy," and Packard's "Guide."

THOUSAND LEGS.

One form of thousand legs is well known by its cylindrical body, by its numerous, short, hair-like feet, and by its habit of coiling its body into a spiral when disturbed.

1. How many segments has the body?
2. How many appendages has each segment?
3. Make a drawing of the thousand legs.
4. What are the chief differences between this animal and insects?

Another common form of thousand legs (*Lithobius americanus*) is that called (wrongly) "centipede," or (also wrongly) "earwig." It is, when full-grown, about an inch long, with a broad, flat head, a brown, shiny back, the segments being mostly of about the same size, with one pair of jointed appendages to each segment. The antennæ are many jointed. It is found under boards, and about rubbish, and manure heaps, where it feeds on insects and earthworms.

1. Examine the jaws and mouth parts carefully; how many pairs of jaws are there?
2. With a lens examine the legs. How many are there?
3. What kind of eyes are there? How many, and how placed?
4. Arrange the legs so they can be distinctly seen, and make a drawing as seen from above.
5. Make an enlarged drawing of the mouth parts as seen from below.
6. What are the differences between this form and the thousand legs mentioned above?
7. In what are the two alike? Both belong to the class **Myriapoda.** Carefully compare them with the insects, and make a list of points common to insects and myriapods; also a list of the characters which insects have and the myriapods do not have; and a list of points peculiar to myriapods.

THE CRAYFISH.

Get a number of live crayfishes. They are usually to be found hidden under stones in the shallow water of creeks. Put into alcohol at least three for each student. Keep some of them alive in an aquarium — a large pan will serve, though the vertical sides of a regular aquarium render it easier to watch the movements of these and other aquatic animals. Let each student have a live crayfish in a fruit-jar. Examine from above, from the side, and from beneath. How many legs does the crayfish use in walking? Frighten the crayfish by suddenly thrusting a pencil at it; how does it effect such rapid locomotion? Touch one of the eyes with the pencil; what follows? Move the pencil slowly toward one of the large claws. What does the crayfish eat, and how does it eat? What are its habits?

The crayfish and lobster are so nearly alike that these directions, though written for the crayfish, will serve fairly well for the latter. Use crayfishes that have been a short time in alcohol. If lobsters are used, get unboiled specimens.

EXTERNAL PARTS OF THE CRAYFISH.

1. The united head and thorax are called the **cephalothorax.**
2. The continuous covering of the two is the **carapace.** The projection of the carapace, above and between the eyes, is the **rostrum.**
3. The hinder, flexible part of the body is the **abdomen.** Count its rings, or **segments.** Bend (flex) the abdomen, and straighten (extend) it repeatedly, observ-

ing how the segments are jointed together, and how they move one upon another.

4. Separate the third ring (counting from the front) from the rings in front of and behind it. To do this hold the cephalothorax and fore part of the abdomen firmly between the thumb and forefinger of the left hand, with the posterior end of the abdomen projecting toward the right hand; then, grasping the dissecting needle firmly with the right thumb and forefinger, thrust the point of the needle obliquely forward between the third and fourth segments, and work it right and left, severing all connection between them without breaking either; with scissors cut the membrane between the under sides of the rings, and entirely separate them. In like manner, detach the third segment from the second. The ring has these parts:—

a. The upper part, the **tergite.**
b. The under part, the **sternite.**
c. The side piece, the **pleurite** (projecting downward).
d. Two appendages, the **swimmerets.**

Observe that each swimmeret has a main stalk and two branches; examine these appendages thoroughly. Lay the ring on its front side, make the branches of the swimmerets diverge enough to appear distinct, and make a drawing of the whole ring as seen from behind.

Compare the other segments of the abdomen with the third.

In the male the appendages of the first and second rings are larger than in the female. Other organs as

well as the generative apparatus present differences in the two sexes, being modified for the performance of special functions in the sexual life, such as the differences in color and markings of male and female butterflies, and the differences between the wings of male and female crickets, already noticed. These differences are known as *secondary sexual characters*. Compare the male and female crayfish as regards the width of the abdomen.

Study carefully the structure and action of the **tail-fin.** Its middle piece is the **telson,** underneath which is the external opening of the intestine, the **anus.**

Remove the telson, and without disturbing the side parts of the tail-fin, separate the sixth abdominal ring from the fifth. Now carefully compare this (sixth) ring and its appendages with the third ring and its appendages.

Are the appendages of the thorax borne upon rings like those of the abdomen? If so, where are the rings? With forceps seize the base of one of the hindmost pair of walking legs, and move it backwards and forwards; are these borne on a distinct ring? Carefully clean the sternum between the other walking legs, and look closely for indications of rings.

5. With the forceps break away one side of the carapace, beginning at the lower edge. This lays bare the white, feathery **gills.** Move the legs of this side back and forth, watching the gills.

6. Study now the hindmost of the walking, or thoracic legs. Count its segments. Observe how the first segment is joined to the body. Flex the leg as far as possible, in every direction, noting the number of

joints, and the motions allowed by each. With the forceps seize the squarish, basal segment of this leg, and pull off the leg.

7. Remove in like manner the leg in front of this, again being careful to get a firm hold of the short, wide segment next to the body. What is the relation between the leg and the gill nearest to it? Lay this leg on a paper in front of the one previously removed. In this way pull off all the legs of one side, from the hindmost to the foremost, laying them in order. Compare them all with the one first taken. In the legs bearing pinchers is there any really new part added, or is the pinching apparatus produced by some change in a part present in all the legs? How do the legs which bear the big claws differ from the walking legs? Compare them, segment with segment.

8. In front of (anterior to) the big legs are several pairs of appendages surrounding the mouth. Probe between them to find the mouth. These mouth parts are numbered from the front, but on account of the way in which they overlap, it is easier to remove and study them in the reverse order.

9. The appendages just in front of the big claws are the hindmost of three pairs of jaw-feet, or **maxillipeds.** Gently raise them, to see how they cover the other mouth parts. Note that these maxillipeds, or foot-jaws, have an inner branch, which meets the corresponding part of the opposite maxilliped, and an outer branch. Observe that both these branches are attached to one segment next to the body. Seize this basal segment, and remove the whole maxilliped. Compare it with one of the swimmerets of the third

ring of the abdomen. In the same way remove the second and first maxillipeds of this side, keeping them in order. Are there gills attached to the maxillipeds? Is there more than one gill on each leg? Are there other gills than those attached to the legs? Pick one of the gills to pieces under water to determine its structure. After removing the gills, look in this region for further traces of thoracic rings.

10. Anterior to the maxillipeds are two pairs of **maxillæ.** These are very thin, and lie close to each other, so that if great care be not taken, they are likely to be pulled off together. Investigate closely, and then, inserting the forceps well down, remove them, one at a time. Attached to the base of the hinder maxilla is a thin, double-spoon-shaped structure, the **gill-scoop.** It lies in the front part of the cavity in which the gills are, the **gill-chamber.** With the forceps move back and forth the second maxilla of the other side, to see how the gill-scoop is thereby moved. The gill-scoop, swinging back and forth, pushes the water out of the front end of the gill-chamber. The water thus expelled is replaced by fresh water, which comes up under the lower edge of the carapace, about the bases of the legs; thus the gills are constantly bathed with water containing a fresh supply of oxygen.

11. The **mandibles** are short, hard, toothed, each bearing a jointed appendage, which curves around the anterior edge of the mandible in a groove. This is the mandibular **palpus.** Move the mandible about to see how it is hinged. Closely fitting against the posterior surface of each mandible is a thin leaf-like structure,

the **metastoma.** (The metastomata differ from the maxillæ in pointing outward and in being undivided.) Remove it and complete the series of mouth parts, — mandible, first maxilla, second maxilla, first maxilliped, second maxilliped, third maxilliped. Remove the corresponding appendages of the other side, lay them in a row facing those of the opposite side, as before removal, but not now overlapping each other, and make a drawing of the series, naming them.

12. The long projections in front of the head are the **antennæ.** Seize one of them with the forceps, and pull about in all directions, to make out the large segment, at its base, under the head. On this basal segment find a small white cone, with a hole at its summit. This is the aperture of the **green gland,** in the head, which acts as a kidney in throwing off certain waste products from the body. Remove the antenna, with the whole of this big segment at its base. What, probably, is the use of the blade-like branch of the antenna just under the eye? Compare the antenna and its branches with a swimmeret.
13. Above the antennæ are the **antennulæ.** Remove one of them and compare it with a swimmeret.
14. In the base of each antennule, just underneath the eye, is the **ear-sac.**
15. With the forceps pull the eye about to see its range of motion. Pull it out by its stalk, and examine with lens and microscope its black tip, or **cornea.** Is it simple or compound?

After removing the cephalothoracic appendages, and the carapace, carefully clean and thoroughly examine the framework of the cephalothorax, still

looking for traces of thoracic rings. The number of cephalothoracic segments can be determined only by counting the pairs of appendages. All writers are not agreed as to this number; some regard the eyes as a distinct pair of appendages, comparable to any pair of legs, and representing a distinct ring; but the eyes seem to develop from the ring which bears the antennulæ. Again, some regard the metastomata as a distinct pair of appendages. The line of division between the head and thorax is also a matter of dispute. Huxley places it between the second pair of maxillæ and the first pair of maxillipeds. Hyatt places the division between the first and second pairs of maxillæ, as the space between these is membranous entirely across the sternal region, while back of this line the parts are hard and firmly soldered together.

The carapace is probably not a consolidation of the dorsal portions of all the cephalothoracic segments, but a backward extension of the consolidated upper parts of the rings of the head; the dorsal portions of the thoracic rings, being thus covered, are consequently no longer developed. In certain lower crustacea the carapace is unquestionably a backward extension of the head-shield (Hyatt). The groove across the carapace has been generally regarded as indicating the line of division between the head and thorax. If this line be traced its extremities will be found to lie between the antennæ and mandibles. Packard states that the carapace, or shield of the head-thorax, may be seen, after close examination, to represent the segments of the antennæ and mandibles,

and is so developed as to cover the other cephalothoracic segments.

16. Make, side by side, three drawings of the crayfish, — a dorsal, a ventral, and a lateral view, — naming all parts.

CRAYFISH CARD.

Take an entire crayfish; separate all its parts, and paste them on a card, as in the case of the grasshopper; arrange the eyes, antennæ, antennules, mandibles, maxillæ, maxillipeds, and thoracic legs, symetrically about the carapace. Make a paper bridge on which to rest the carapace. Separate the rings of the abdomen, string them on the paper bridge, and place opposite each its appendages, remembering that the side parts of the tail-fin are appendages of the sixth ring. Draw in your note-book all the parts as arranged on the card, with the name beside each part.

INTERNAL STRUCTURE OF THE CRAYFISH.

The better dissecting pans have a thick layer of wax in the bottom, or a sheet of cork weighted with lead, to which specimens may be pinned, and dissected under water. Very good cheap dissecting pans may be made as follows: take oyster-cans that have been opened on one side, and cut out this side, leaving a margin half an inch wide. Bend this margin down inside. Cut a piece of shingle or cigar-box cover for a false bottom, leaving it a little long, so it will wedge in tightly and not float up when water is poured in.

For this work use lobsters, or as large crayfishes as possible. Place the crayfish in the dissecting pan, and cover it

with water. Pin it to the bottom, through the telson, and through the big claws. Observe a groove, curving lengthwise, on each side of the back of the carapace. Insert the point of one blade of the scissors under the hinder edge of the carapace at one side. Cut forward, a little outside the above-noticed groove, to the groove which separates the head from the thorax. Break away the whole of the side of the carapace. Push the gills downwards, and cut them off at their point of attachment below.

Observe the thin wall separating the cavity in which the gills were, the gill-chamber, from the body cavity. Clear away the other side likewise. With the forceps pick away the narrow cover of the body cavity carefully, as the heart lies just under the carapace.

1. The **heart** is an oblong, whitish body. Look for holes in its upper surface, and for small white tubes running forward from it toward the head. With the forceps gently lift the hinder end of the heart; note its angularity.

   There are two holes in the top of the heart, two beneath, and one on each side. These holes are guarded by lip-like valves on the inside, so that when the heart contracts, the blood cannot flow out through the holes, but is driven out through the arteries to the various parts of the body. From the different parts of the body the blood goes to the gills. Returning from the gills, it enters the cavity in which the heart lies, the **pericardial cavity.** As the valves at the openings of the heart open inward, the blood readily flows into the heart when it expands.

2. Under the heart, and projecting in front of it, are the reproductive organs: in the female, the yellowish ovaries, in which the spherical eggs may be distinguished; in the male, the whitish testis occupies a corresponding position. The **ovary** on each side sends downward a tube, the **oviduct,** or egg-tube, to the first segment of the third thoracic leg, where it opens externally. The **testis** has a much longer, coiled white tube, which opens on the first segment of the hindmost thoracic leg.
3. Carefully cut away the roof of the head. The space within the head is almost completely occupied by the **stomach,** a roundish sac, with a thin wall, in which is a hard framework. Gently scrape away the soft tissues around the stomach, and examine it closely. Observe the narrow **gullet** or **esophagus** leading from the mouth to stomach.
4. Along the sides of the posterior end of the stomach and the anterior end of the intestine lie large reddish masses, the **liver.** Pick one of these masses to pieces to learn its structure. Find the duct leading from each liver into the intestine.
5. Observe the white **muscles** which extend forward from the abdomen along each side of the body cavity.
6. Beginning at the front end of the abdomen, cut with scissors through the roof of the abdomen to the telson, on each side. Seizing the fore part of this roof with the forceps, carefully lift it and turn it backward. A thin layer of white muscle may adhere to it, or may remain connected with the organs in the abdomen. This is made up of the muscles that

straighten (extend) the abdomen. Pick it away carefully with the forceps.

7. Running lengthwise, in the middle line, is the **intestine,** a thin-walled tube, often of a dark color from its contents. Trace it back to the anus, and forward to the stomach. Carefully remove the intestine.

8. A large mass of muscle remains. This is composed of the muscles that bend (flex) the abdomen. Draw the point of a knife-blade or dissecting needle along the middle line of this muscle, along the bottom of the groove in which the intestine lay. After a thin layer has been cut through, the whole muscle may be easily separated into two rolls the whole length of the abdomen. Pushing these carefully aside, find in the middle line of the floor of the abdomen a slender white **nerve cord,** with enlargements at intervals. How many of these enlargements, **ganglia,** are there in the abdomen? What relation do the ganglia have to the segments? Observe the branches, **nerves,** given off to the muscles on each side. Trace the nerve cord forward to the thorax, where it disappears in the hard framework of the floor of the thorax. Break away as much of this framework as is necessary to follow the cord to the head. Make out that the cord is double. How many ganglia are there in the thorax? Note the branches extending to the legs and other organs. From the large ganglion back of the gullet trace two branches forward, one on each side of the gullet, till they unite in a large ganglion above the gullet, thus forming the **esophageal collar.** From the ganglion above

the gullet trace nerves to the eyes, antennæ, and antennulæ.

9. Cut open the stomach, wash it out with water, and look on its inner walls for teeth.
10. Study the joint in one of the big pinchers. Pick out the muscle from the end of the segment, and find the thin, tough, white tendons. Seize these with the forceps and pull alternately, to see how the claw is shut and opened.
11. In what characters is the crayfish like the grasshopper? In what do these animals differ?
12. Why should the name **Crustacea** be applied to such animals as the crayfish?

THE DEVELOPMENT OF THE CRAYFISH.

The eggs are glued in masses to the swimmerets, under the abdomen of the female, and thus carried till they are hatched, and for some time afterward the young cling to the swimmerets. In its growth the crayfish sheds its crust, or **moults**, several times. In this process the carapace separates from the abdomen above, and cracks along the back. By a series of severe efforts the crayfish extricates itself, at first soft, defenceless, and correspondingly timid. Great difficulty is experienced in withdrawing the legs; often they are broken off in the effort to withdraw them. The legs are frequently broken off at other times, but grow out again.

Read "The Crayfish," Huxley; the chapter on "The Fresh-water Crayfish" in "Practical Biology," Huxley and Martin.

THE SOW-BUG.

Sow-bugs are usually to be found under boards and stones, and in other damp places. Get the largest specimens for this study.

1. The first part is the head, or carapace.
2. Find and describe the eyes.
3. What are the peculiarities of the antennæ?
4. The jaws and maxillæ are closely pressed together, forming a short, blunt projection under the head. The tip of this blunt proboscis is usually black. A longitudinal groove shows the line of union of the hinder maxillæ. By pinching the body of a live sow-bug, the mouth is sometimes more clearly shown by the exudation of a liquid, as in the case of a grasshopper.

   Where is the line of division between the head and thorax? Count the appendages which may be supposed to belong to the head; how many rings do these indicate?
5. The line of division between the thorax and abdomen is indicated by an abrupt change in the size of the segments. How many segments has the thorax?
6. How many segments are there in the abdomen?
7. How many pairs of legs are there? How many segments has each leg? Do the legs all extend in the same direction?
8. A series of thin, over-lapping plates under the abdomen are the gills. In the anterior plates observe the white **air-chambers.** Beginning at the foremost of these gills, pick them apart with a needle. Remove them

in this way, and with a lens make out their shape and arrangement.

9. Under the thorax of the female there is a series of thin membranes attached near the bases of the legs. These are the egg-covers. The eggs, after being expelled from the body, undergo their development in the space under the thorax enclosed by these egg-covers. Look for specimens carrying eggs in this manner.

10. In what respects are the sow-bug and crayfish alike? In what respects do they differ from each other?

    The crayfish and sow-bug both belong to the **Crustacea.** The class Crustacea is divided into several orders. The order to which the crayfish belongs is the **Decapoda,** or ten-footed; the sow-bug belongs to the order **Tetradecapoda,** or fourteen-footed.

See Chapter XVIII of Morse's "First Book of Zoölogy."

CYCLOPS.

Along the sides of aquaria, and sometimes in drinking-water, there may be seen minute white animals swimming with a jerky motion. Cyclops has a pear-shaped body, and is just large enough to be seen readily with the naked eye. The females carry two egg-masses attached to the sides of the abdomen. With a lens, watch these animals through the side of the aquarium. Place a female cyclops with a few drops of water in a watch-crystal, or

on a piece of glass. Examine under a three-legged lens or under a low power of the microscope.

1. The foremost division of the body is the **carapace.** How many segments has the thorax?
2. The **egg-sacs** are attached to the first ring of the abdomen.
3. The **eye**; note its color, position, shape, and parts.
4. The **antennæ** and other appendages.
5. How does cyclops swim?

Make a careful drawing of cyclops as seen from above.

Cyclops belongs to the order **Entomostraca** (water-fleas). Read "Anatomy and Metamorphosis of Cyclops," in Brooks' "Handbook of Invertebrate Zoölogy."

OTHER CRUSTACEA.

The lobster is almost exactly like a crayfish, only larger. If a lobster can be obtained, carefully compare it with the crayfish. Shrimps are also very much like crayfishes. Crabs have wide bodies and very short abdomens, folded closely under the body. The structure of crabs, both internal and external, is essentially the same as that of crayfishes. The crab which is so much used for food has the hinder pair of legs developed as paddles for swimming, the outer segments being flattened. This crab swims sideways. Just after moulting it is known as the "soft-shell crab."

The little oyster crab, which often comes to us with our oysters, is not a young crab, but is the female of one of the smaller species of crabs.

The hermit crab backs into the empty shell of a sea-snail, thus protecting the soft hinder parts of his body, and with his head and anterior appendages projecting, crawls about, dragging his house with him. When the hermit outgrows his shell, he exchanges it for a larger one. When first hatched it is like other crabs.

The sand crab runs rapidly on the beach, and when pursued, and not near its hole, quickly buries itself in the sand, leaving only the black tips of its eyes exposed. This crab is nearly white.

The fiddler crab is small. The male has one large claw, which it holds across the front of its body. The other claw is very small, the two suggesting the violin and bow. It lives in holes between high and low tide marks. The writer has seen these crabs covering the beach for many rods, so thickly crowded as almost to touch each other, making a loud rustling noise as they shuffled away from their uninvited visitor.

Lobsters, crabs, and shrimps live in salt water.

Some small crustaceans, found in ponds, swim actively about, enclosed in a bivalve shell, formed by the growth of the carapace, which they can open and shut.

Collect a variety of the common small crustaceans, keep them in a fruit jar, and study their habits.

Consult "Worms and Crustacea" in Hyatt's "Guides for Science Teaching," "Packard's Zoölogy," and Huxley's "Anatomy of Invertebrated Animals."

Look over the descriptions of the crayfish and sow-bug, and make a list of the characters common to the two. Let this list represent the characters of Crustacea generally. Place side by side (1) the list of characters common to all

the insects studied, (2) the characters of spiders, (3) the characters of myriapods, (4) the characters of crustaceans, and by comparing these four lists make the following: —

1. A list of characters which they all have in common.
2. A list of characters which insects have, but which the others have not.
3. A list of characters which spiders have, but which the others do not have.
4. A list of characters which myriapods have, but which the others do not have.
5. A list of characters which crustaceans have, but which the others do not have.

Which are more striking, the **differences** or the **resemblances,** in thus comparing these four groups?

The four classes, **Insecta, Arachnida, Myriapoda,** and **Crustacea,** constitute the **branch** of the **animal kingdom** called the **Arthropoda.**

List 1 ought to be an approximate definition of the branch Arthropoda.

THE EARTHWORM.

Place a live earthworm on a newspaper on the table, and watch its motions. How does it crawl? Is the same end always foremost? Are the two ends alike? Near the anterior end is the thick white **girdle**; is it a complete girdle? Count the segments; are they all alike? Compare the upper, **dorsal,** surface with the under, or **ventral,** surface. A dorsal vessel can usually be seen under the dorsal surface; watch for pulsations. With the forceps

seize the worm near the posterior end and drag it backward; is there resistance? Repeat, and listen attentively. Lay the worm over the tip of the forefinger, and drag it backward and forward. Look for fine **spines**; how are they arranged, and in what direction do they point? Note the **mouth** opening at one end, and the **anus** at the other. Draw as seen from above (dorsal view).

DISSECTION OF THE EARTHWORM.

Use the dissecting pan as for the crayfish. Half fill the can with water, and renew if it becomes muddy during dissection. Have in readiness two dozen pins.

Kill a large earthworm by putting it into a tumbler and covering it with ether or alcohol.

1. Lay the specimen lengthwise in the middle of the dissecting pan, stretch it, and pin it firmly at each end. With sharp, fine-pointed scissors cut through the skin of the back, near the posterior end, continuing the cut forward a little to one side of the middle line. Stretch the edges of the skin out to the sides, and pin down, slanting the pins so they will be out of the way.
2. If a milky liquid be found, place a drop of it on a slide, cover it with a cover-slip, and examine with a high power of the microscope. White blood corpuscles should be seen.
3. As soon as the edges of the cut are separated, the **intestine,** usually of a dark color, from its contents, is seen.
4. Along the top of the intestine runs the **dorsal vessel.** This is perhaps not a true "blood-vessel," for many regard the milky liquid, above noted, as the real blood.

5. Observe the muscular **partitions** between the segments; what is their relation to the intestine? Carefully compare the partitions with the external markings and the sets of spines. Are there as many segments as are indicated by the external appearance?
6. The brownish substance along the top of the intestine is the liver.
7. Continue the cut to the anterior end, being very careful not to cut the intestine, especially in the part anterior to the girdle. Pin well out. Cut the partitions down at the sides, to free the inner structures.
8. In the region of the tenth segment are several roundish white bodies, — **reproductive organs.**
9. Alternating with these are several red masses. These are side branches of the dorsal blood-vessel, which curve downward on each side of the gullet, to unite with a ventral blood-vessel, thus forming rings around the slender gullet. These rings have enlargements, thus resembling necklaces.
10. Back of the reproductive organs are two enlargements of the digestive tube, different from the intestine. The foremost of these is the **crop**, the hinder is the **gizzard.**
11. In the first six segments is a wide portion of the digestive tube, the **pharynx.** Carefully dissect away the thick muscular partitions, to see it more clearly. This pharynx is used as a proboscis, being protruded from the mouth and inverted.
12. The pharynx narrows behind into the **gullet.** Trace this back under the reproductive organs to the crop. The gullet is the narrowest part of the digestive tube, and if the reproductive bodies have been sufficiently

studied, they may be dissected away, to disclose the gullet more fully. Review now the whole digestive tube, pharynx, gullet, crop, gizzard, intestine.

13. Under the intestine is a **ventral vessel.** Find its side branches.
14. Cautiously dissect away the intestine and find under it a slender white thread, the **nerve cord,** having swellings, or **ganglia,** in each segment. Trace this nerve cord to its posterior end. Then trace it forward. Under the anterior part of the pharynx it divides, sending a branch up on each side of the pharynx. These branches unite in a large, double ganglion above the anterior end of the pharynx. This **nerve collar** is similar to that found in the crayfish and in insects.
15. The thin outer skin, or **cuticle,** which easily peels off in alcoholic specimens, was probably noticed in cutting along the dorsal wall. Observe the pearly lustre of the cuticle. Under the true skin is a layer of muscle, with fibres running circularly. Underneath this is a second layer of muscle, whose fibres run lengthwise. By the contraction of the circular fibres the segments are made narrower and longer; thus the body is extended. If the spines are held pointing backward, the body will be pushed forward. When the longitudinal fibres contract, the body is shortened, and, owing to the direction of the spines, is pulled ahead.
16. The reproductive organs are alike in all the individuals of a given species of earthworms. All lay eggs. There are no males, no females. They pair, each fertilizing the eggs of the other. Animals of this

kind, in which the sexes are united in the same individual, are called **hermaphrodites.**

17. There are no lungs, no gills. Oxygen is taken by the blood as it circulates, through the skin.
18. There are no eyes, but the first two segments seem to be sensitive to light.
19. The worm, in digging a new hole, or deepening an old one, swallows the soil, and passes it through its intestine, the partly decayed vegetable matter in the soil furnishing nourishment to the worm. The coiled castings at the tops of the holes have probably been noticed by all. In damp weather the worms come to the surface to draw leaves, twigs, and seedling plants into their holes. These holes are sometimes six feet deep. It is found that the leaf is rolled together and drawn into the hole with the stem pointing up. Taken an inch or two below the surface, the leaves soon become softened, and in a partly decayed condition are eaten. In this way, without the aid of teeth or hard jaws, the worm obtains food solely by the suctorial power of its proboscis.
20. Make a drawing showing the whole digestive canal as seen from above. Draw a cross-section of the body (*i.e.*, what is seen if the body is cut across), and a vertical longitudinal median section (as seen by splitting lengthwise, from top to bottom, in the middle line).

RANK OF EARTHWORMS AMONG ANIMALS.

Animals are ranked according to the number of things they can do, and do well. The earthworm has many parts, but they are all nearly alike, and do not enable it to

do many different things. A part of an animal having a special work to do is called an **organ,** and its work is its **function.** The earthworm has many organs, but few functions. Apply this principle to man and an ape. Each has four limbs. The ape is called four-handed, but has no good hands; he cannot handle things well. He has not good feet; he cannot walk well. What is the one thing he can do well with his four foot-hands? How many distinct functions has man with his hands and feet? Multiplication of parts without corresponding variety of structure and function mark an animal as low in rank.

Another respect in which the earthworm is low is this, — the head end is not much better than the tail end. There is no distinct head. At first glance there is not much difference. Many worms similar to the earthworm can be cut in two, and each part lives; the hind part developing a new head, and the fore part a new tail. The part of the nervous system in the head is not greatly different from other parts. Just in proportion as the head rises in importance, and the whole set of organs centre around it, the animal rises in the scale. Apply this test to the earthworm and crayfish, crayfish and crab, bee and dragon-fly.

Compare insects with earthworms in rank from another point of view. Most insects, before reaching the adult state, pass through a worm-like stage. Crabs are at first like crayfishes in having a well developed abdomen. As the crab grows, the abdomen shortens, and the head becomes more prominent. What would this indicate as to the relative rank of worms and insects? of crayfishes and crabs? Worms constitute one branch of the animal kingdom. In this branch, **Vermes,** are the leech, trichina, tapeworm, with many animals very unlike the earthworm

in appearance. In classifying animals, the more significant characters are internal structure and mode of development rather than mere outer form and general appearance. Most worms have gills. Worms never have jointed appendages.

There is a group of slender worms called hair-worms. "They sometimes occur in horse-troughs, whence they are supposed by the ignorant to be transformed horse-hairs."

In what characters are worms like Arthropods? How do worms differ from Arthropods?

Read the life history of the tapeworm and the trichina.

Read Darwin's "Vegetable Mould and Earthworms," the description of the earthworm in Huxley's "Anatomy of Invertebrated Animals," "Anatomy of the Earthworm" in Brooks' "Handbook of Invertebrate Zoölogy," "Worms and Crustacea," No. VII in Hyatt's "Guides for Science Teaching."

THE FRESH-WATER CLAM.

STUDY OF THE LIVE CLAM.

Look for fresh-water clams in the sandy bottoms of creeks and rivers. They may be found nearly buried in the sand or mud. If no better aquarium be at hand, take an old tub, half fill it with water, and have two or three inches of sand at the bottom. Drop several clams into the water, and note carefully the place and position of each. On the next day see if any of them have changed either place or position. The part uppermost, in the natural position, is the back. Look near one end, where the shell opens a little, for two oval holes. These are the **siphons**; gently

touch the margin of one of them. What follows? The water enters one of these openings and comes out of the other. Prove the action of each by stirring up a little mud, to show the currents; or take a small glass tube, dip the lower end into ink, or finely divided indigo in water, then placing a finger over the upper end of the tube, lift out a little of the ink. Keeping the finger tightly on the top of the tube, thrust the other end down to a point just above the siphonal openings; then raise the finger and release some of the ink. In some way prove the existence of these currents. Let each pupil have a clam in a fruit-jar, with sand enough to support the clam. Keep the clams alive for a week or more, and watch them daily.

THE CLAM-SHELL.

If a live clam is used, place it on a plate, or in the oyster-can.

1. Notice the two parts of the shell, — the **valves.**
2. The edge along which the shell opens is the **ventral margin.**
3. The edge by which the two valves join each other is the **dorsal margin,** or **hinge margin.**
4. The concentric lines parallel to the ventral margin are the **lines of growth.**
5. The raised point around which these lines centre is the **beak,** or **umbo.**
6. The umbones are nearer the front, or anterior, end of the clam.
7. Toward the posterior end, back of the umbones, between the valves, and uniting them, is the **hinge-ligament.**

8. Hold the closed shell with the umbones and hinge-ligament uppermost, the latter nearer, and the former pointing away from you.

   The end pointing from you is the **anterior** end.
   The end pointing toward you is the **posterior** end.
   The upper edge is the **dorsal** margin.
   The lower edge is the **ventral** margin.
   The half shell to your right is the **right** valve.
   The half shell to your left is the **left** valve.
   Fix these relations firmly in mind.

9. Make a drawing of the clam as seen from one side, naming all the parts.
10. Draw as seen from above, placing this drawing alongside the side view.
11. Draw the clam as seen from the anterior end.
12. Observe the color, the degree of cleanness, and general condition of the different parts of the shell, and consider the relations between these facts and the position of the clam when first found.

DISSECTION OF THE CLAM.

Put the live clam for a few minutes into water as warm as the hand can well bear. This causes the muscles to relax, so that the shell can be readily opened. If warm water cannot be easily obtained, the clam may be opened with a strong knife, after reading the directions which follow.

Pry apart the two valves, and insert a small block to keep them from shutting.

1. Observe a soft white membrane, the **mantle,** adhering to the inner surface of the shell. Now hold the clam

in the left hand, with the hinge-margin resting in the palm of the hand, and the anterior end toward you. Insert the blade of a knife between the mantle and the upper (left, if held as directed) valve, and gently separate them by sliding the blade of the knife along the inner surface of the shell. In this way proceed backward, around the posterior end of the shell, then forward along the dorsal margin. Back of and below the hinge is a large white muscle, which extends directly across from valve to valve. Cut this off close to the left valve. In like manner loosen the mantle at the anterior end, and find another muscle connecting the two valves near the anterior dorsal margin. Sever as before, close to the left valve, and loosen the mantle completely from the upper valve, and turn this valve back like the lid of a box. What makes the valve spring up after the muscles are severed?

2. Lay the clam in a deep plate, or in the oyster-can, and cover it with water. Renew the water as often as it becomes turbid.

Observe that the left mantle lobe now covers the body, and that the right lobe lines the right valve. Notice the thicker margin of the mantle. Pinch this thick edge; what follows? Observe a thin, dark-colored membrane bordering the edge of the shell. This is an extension of the outer covering, or **epidermis,** of the shell. Scrape off some of the epidermis to see its relation to the limy shell. Carefully study the relations of the epidermis to the mantle. Turning to the uninjured mantle lobe, pinch the edge of the mantle, and observe the effect on this free border

of the epidermis. Trace the right and left mantle lobes to their points of union before and behind.

3. Examine the thick, dark-colored, hinder edge of the mantle lobes, and see how by their manner of meeting they form the two short tubes, the **siphons,** seen in the live clam; prove the great sensitiveness of the margins of these siphon tubes. Are the margins of the two openings alike?
4. Examine the ends of the **anterior** and **posterior adductor muscles** where they were cut off in opening the shell; scrape away any part of these muscles that may remain attached to the left valve, and note the marks or **muscle scars** which are shown.
5. Turn the mantle lobe back as far as it will go, and observe the soft **abdomen**; its tough lower border is the **foot**; prick it with the dissecting needle, and observe what follows.
6. Along each side of the abdomen and extending back of it are two thin membranes, the **gills,** showing vertical parallel markings (sometimes the outer gill is thick, and of a dark color); study closely the relations of the gills to each other, to the body, and to the mantle. With a knife scrape off a little of the surface of the gill and examine under the microscope to see the vibratory motion of the hair-like projections, or **cilia,** borne on the cells thus obtained.
7. In front of the gills, on each side of the body, are two thin, triangular flaps, much smaller than the gills, the **labial palpi.**
8. Raise the hind border of the left mantle lobe, and observe that the gill next to the body unites with the corresponding gill of the other side, thus forming a

separate channel above the gills, into which the upper siphon leads, while the lower siphon leads to the lower cavity, outside of and below the gills.

9. With the thumb and all the fingers of the left hand seize the left lobe of the mantle and pull it toward the ventral margin, thus drawing the body away from the dorsal margin. Just under the hinge a pale organ may be seen, pulsating every few seconds; this is the **heart.**

10. Holding the mantle stretched, again examine the upper siphonal opening; probe to see how it extends forward above the united hinder portion of the gills. In the upper part of this cavity find a tube running back over the posterior adductor muscle, and ending in a conical elevation; this tube is the intestine, and the opening at its end is the anus; hence the siphon leading from this cavity is called the **anal siphon**; the lower siphon, which conducts water to the gills and mouth, is called the **branchial siphon** or **gill siphon.** Examine the gills from above, *i.e.*, examine their dorsal margins; observe that the two outer walls of each gill are a short distance apart at this edge, while below these walls unite, so that if the gill be cut across, these walls, as seen at the cut, are like the letter V. These diverging walls are connected by cross partitions, thus forming a series of compartments within the gill, whereas if these partitions were absent, each gill would be a deep, narrow, undivided trough. The lateral walls of the gills are sieve-like, and the surface of the gill and the edges of the holes are covered with cilia. The vibrations of these cilia drive the water which is around the gill through

these holes into the cavities within the gill; the water from each compartment of the gill passes up into the chamber leading to the anal siphon.

Beginning at the upper edge of the anal siphon, in the middle line, cut carefully forward just above the intestine as far as the umbo. This lays bare the cavity in which the heart lies, the **pericardial cavity.** Carefully cut away the thin covering of this cavity and make out the following parts:—

a. The large yellowish **ventricle** in the anterior part of the cavity; time its pulsations; observe that the intestine runs directly through the ventricle, though it has no more communication with the ventricle than a stove pipe has with a room it passes through; an artery runs forward from the ventricle along the upper surface of the intestine; another artery runs from the ventricle backward under the intestine. Again pull the mantle ventral-ward to show *b.*

b. A thin sac, triangular as seen from the side, with its apex joining the ventricle, and its base attached just above the upper edge of the gills; this is the left **auricle.** Each auricle receives the blood from the gills of the corresponding side.

11. Just in front of the posterior adductor muscle is the dark **kidney.**

12. Above the kidney, and in front of the posterior adductor, is a small muscle, which extends backward from the side of the body to join the valve near the posterior adductor. This muscle pulls the foot backward.

Look near the anterior adductor for similar muscles; what work do they perform?

13. To find the **mouth,** hold the clam, anterior end uppermost, still attached to the right valve, in the left hand; press down the point of the foot, and find the mouth opening below the anterior adductor; observe that the two outer palpi unite above the mouth, and the two inner palpi unite below the mouth. Back of the anterior adductor a dark-colored mass may be seen within the body; this is the **liver,** which surrounds the stomach; the intestine has several coils in the body before emerging on the dorsal surface a short distance in front of the heart. The intestine can be traced much better in an alcoholic specimen.
14. Beginning at the posterior adductor, cut away all the free flap of the left mantle lobe, following the upper edge of the gills (being careful not to cut away the labial palpi) to the upper edge of the anterior adductor. Make a drawing of all the parts above named, as they lie in the right valve.
15. Remove the remaining soft parts in as good condition as possible, and put into alcohol, for the dissection of the nervous system.
16. Make a drawing of the inside of one of the valves, showing the hinge, the muscle scars, and any other markings that have any significance. Sometimes there can be distinctly seen a line running near, and parallel to, the ventral margin, along which the upper edge of the thicker portion of the mantle was attached; this is the **mantle line,** or **pallial line.**
17. Some clams have **hinge teeth,** by which the dorsal edges of the valves are more firmly held together

when the shell is shut. The irregularly shaped teeth near the umbones are the **anterior,** or **cardinal** teeth; back of these are the long, narrow **posterior,** or **lateral** teeth.

18. Take an empty shell with the valves still hinged together; cut and fit into this shell a piece of paper showing the shape of the whole mantle. Make also a plaster of Paris cast of the inside of the shell.

19. Wipe dry a number of shells and weigh them. After thoroughly roasting them in a fire, weigh them again. If the shells are not burnt too long, some of the animal matter may remain in the form of layers of charcoal between the layers of lime.

20. Put a shell into dilute acid to dissolve out the lime. Observe the animal matter remaining undissolved. Compare the effect of acid on equal pieces of burnt and unburnt shell.

21. Carefully pick to pieces a burnt shell and distinguish an inner and an outer portion of the shell, the line of division between which appears on the inner surface of the shell along the mantle line. Make out the successive layers of the outer part which were built by the outer part of the mantle, and the layers formed by the thinner, inner part of the mantle.

22. Break a burnt shell across from the umbo to the ventral margin, and make a drawing of the edge thus exposed, showing the arrangement of these sets of layers. File a groove from the umbo to the ventral margin of a fresh shell, and break it across. Compare the edges of this with the corresponding part of the burnt shell.

THE NERVOUS SYSTEM OF THE CLAM.

This dissection requires the utmost care and patience. Take a clam that has been hardened in alcohol, or by boiling. Dissect under water; rinse the specimen often.

1. Immediately under the posterior adductor muscle find a double, yellowish body; this is composed of the two **parieto-splanchnic ganglia;** dissect away the thin membrane covering them.
2. From these ganglia trace nerves backward to the gills and to the posterior borders of the mantle lobes; trace also two nerves forward, carefully dissecting away the soft parts that cover them anteriorly, and trace them to the sides of the mouth where they join 3.
3. The **cerebral ganglia:** these lie near the surface at the bases of the **labial palpi.** Trace a small nerve which connects the two cerebral ganglia over the mouth.
4. From each cerebral ganglion trace nerves backward and downward to 5.
5. A pair of orange-colored **pedal ganglia,** lying together deeply imbedded between the foot and the abdomen.

In the alcoholic specimen the stomach and intestine may be traced. Cross-sections of alcoholic specimens may be made with a razor, which show admirably the relations of the different parts of the clam.

THE DEVELOPMENT OF THE CLAM.

If the outer gills be thick and dark-colored, open one of them, remove some of its contents, and mix with water

in a watch-crystal or on a slide. Examine with a one-inch objective or a lens. Make a drawing of the young clams. Compare the shapes of the young and adult. Watch carefully for movements of the young clams.

The shell grows by additions deposited by the mantle on the inner surface of the valves. Each new layer projects beyond the others; so the shell grows in width as well as thickness. Where is the thickest part of the shell? If a thin piece of glass is slipped between the mantle and its corresponding valve, and the clam be kept alive, the shell substance is deposited over the glass, and the glass becomes buried in the nacreous matter of the internal layer. Grains of sand become pearls by the secretion of similar nacre around them.

Read "The Fresh-water Mussel" in Huxley and Martin's "Practical Biology"; "The General Anatomy of a Lamellibranch" in Brooks' "Handbook of Invertebrate Zoölogy"; No. VI of Hyatt's "Guides for Science Teaching"; Packard's "Zoölogy."

THE SNAIL.

A dipper with a perforated bottom, attached to a wooden handle, will be found convenient in scooping up the sand and mud from the bottoms of ditches and streams; the dirt being sifted out, the shells and other objects will be left behind. Get a number of live snails, and keep them in a fruit-jar.

1. The broad disk on which the snail creeps is the **foot.**

2. The "horns" are the feelers, or **tentacles**; touch them; what would seem to be their use?
3. The dark spots at the bases of the tentacles are the **eyes**; are they borne on a stalk in any common snails?
4. Watch the snail crawling on the glass; near the front of the foot the **mouth** may be seen; observe its opening and shutting as the snail gathers food from the surface of the glass. Do snails clean the glass or foul it?

   Most snails have a ribbon-like tongue, fastened at each end, and covered with teeth; as this tongue is applied to an object, and drawn rapidly back and forth, it acts like a rasp; in this way some marine snails bore holes through the shells of other mollusks and feed on them.
5. Many snails have gills; others breathe by a simple lung. Watch the snails, to see if any of them come to the surface to get air; how is this done?

THE SNAIL-SHELL.

1. The pointed end is the **apex.**
2. The opening at the large end is the **aperture.**
3. The outer edge of the aperture is the **lip.**
4. The lines parallel to the lip are the **lines of growth.**
5. The spiral groove on the outside is the **suture.**
6. The turns of the shell between the groove are the **whorls.**
7. The whorls, taken together, make the **spire.**
8. The lid closing the aperture is the **operculum;** is this present in all the snails you find?

Make a drawing, naming all the parts, of the snail-shell with the aperture toward you; with the aperture away from you; with the apex toward you.

Lay the snail-shell beside a common screw; if the whorls turn like the threads of the screw, it is a **right-hand shell**; if they turn the other way, it is a **left-hand shell**; the right-hand shells are sometimes called **dextral,** and the left-hand, **sinistral.**

Clams, snails, and oysters belong to the branch of the animal kingdom called **Mollusca**; the clam is a **bivalve**; the snail is a **univalve.**

Read Morse's "First Book of Zoölogy," on snails and clams.

PARAMŒCIUM.

In a tub, or aquarium, in which clams have been kept, a thin white film may form on the surface of the water. This is more likely to occur if some of the clams die and the water gets "bad." Place on a slide a drop of this water with some of the white film, with a piece of paper under the edge of the cover to keep from crushing the animalcules. Examine first with a low, then with a high power of the microscope.

Paramœcium is somewhat slipper-shaped, swimming actively by means of vibrating, hair-like projections, or **cilia**; are these of the same size on all parts of the body?

Find, on one side of the body, a widely open, funnel-shaped cavity, extending obliquely backward into the body; this is the **vestibule**; the narrower, inner part of this funnel-shaped cavity is the **gullet,** or **esophagus**;

observe that this whole cavity is lined with cilia, and that they are in active operation, producing currents in the water, by which food-particles are swept into the mouth; the gullet does not lead by a continuous tube to a definite stomach, but any part of the body within acts as a stomach. When a collection of food-particles has accumulated at the lower end of the gullet, the mass, by a contraction of the body, is forced further into the soft substance of the body, leaving the blind end of the gullet as it was before. By sifting some finely powdered indigo into the water this process of taking food may be better seen. These animals seem to have little or no sense of taste, as indigestible particles are readily taken in. There is a regular place for ejecting such indigestible matter; watch patiently to make out where this is.

Note the changes of shape which the body undergoes as it forces its way through narrow places, between particles of sediment in the water.

If a specimen that is pretty quiet be carefully watched, a large transparent space will be seen at some point in the body; this, after remaining visible for some twenty or thirty seconds, will suddenly disappear, and gradually reappear; this is the **contractile vesicle.** In some species there are two contractile vesicles.

Watch closely the food-masses; do they retain their original size? Do they maintain a fixed position?

Make a drawing showing —

1. The shape of the body.
2. The vestibule and gullet.
3. The food-masses.
4. The cilia.
5. The contractile vesicle.

In swimming, is the same end always foremost?

Read "The Structure of Paramœcium" in Brooks' "Handbook of Invertebrate Zoölogy."

THE BELL-ANIMALCULE (VORTICELLA).

Collect leaves and grasses that have fallen into water, and the stems and leaves of water plants from ponds and ditches; place some of these leaves in a plate of water, and examine them closely; with the naked eye there may sometimes be seen on them little patches resembling mould; when observed more closely these appear to be in the form of minute tufts, if these tufts shrink back when touched, take a lens and examine carefully; cut out a part of a leaf bearing these clusters, put on a slide with a drop of water, cover with a cover-glass, and examine with a one-inch objective.

Sometimes these tufts, which are colonies of Vorticellæ, may be attached to the sides of an aquarium, or jar, in which clams have been kept.

Some kinds of Vorticellæ are not in colonies, but are borne singly on independent stalks.

When one is found, note, using a one-inch objective:—

1. The bell-shaped body.
2. The contractile stalk; suddenly jar the table, or stage of the microscope, by tapping with a hard object; what follows?

Put on a high power objective and make out the following parts of the body:—

1. The projecting outer rim is the **peristome.**
2. The central **disk,** projecting above the peristome.
3. The short, hair-like **cilia** on the border of the disk and peristome; watch the motion of these cilia, and the currents of water thus produced.
4. A depression between the peristome and disk, deepening at one place to make the **vestibule,** or entrance to the **gullet,** which extends a short way into the body.
5. A clear space, just under the disk, is the **contractile vesicle;** watch this closely for some time; what changes occur?
6. At various points in the body may be seen rounded masses, the **food-balls;** do they remain of the same size, and keep the same place?
7. Make drawings showing the above points.

Watch patiently to see the accumulation of particles at the lower end of the gullet; after a time this mass may be seen to be pushed into the body. This forms one of the food-balls. These food-balls may be seen moving on in a circle within the body. Ejection of undigested matter takes place near the mouth. Sometimes two vorticellæ are found on one stalk; by watching it patiently it may be found that the vorticella is dividing to form two vorticellæ; this is one way these animals have of reproducing. What powers and faculties have you and the vorticella in common?

Read "The Structure of Vorticella" in Brooks' "Handbook of Invertebrate Zoölogy."

AMŒBA.

One of the simplest forms of animal life is **Amœba.** It is found in standing water, where it lives on the leaves of submerged plants or in the mud and ooze at the bottom.

Scrape up a thin layer of the ooze and allow it to stand a few days.

Place a drop of such water, with a little of the sediment, on a clean slide, and cover with a clean cover-slip; if there be no solid matter in the drop of water, lay a strip of paper on the slide before putting on the cover-slip, letting one edge of the cover rest on it. Examine with a high-power objective.

The amœba is like a minute drop of jelly, pale (nearly colorless), with a more dotted central portion. Its most noticeable characteristic is its slow, peculiar mode of changing its form.

The following parts of the body should be made out:—

1. A clearer outer margin.
2. A dotted or granular inner portion.
3. A clearer, round body, in the granular part, called the **nucleus.**

Study carefully the movements of the amœba; first a part of the clear outer portion bulges out, or is sometimes thrown out as a long projection, called a **pseudopodium**; then the granular part flows into this, and by repeating this process the amœba creeps along with a slow gliding motion, though sometimes the pseudopodia are thrust out and retracted without moving the body as a whole; carefully watch the beginning and the whole process of forming a pseudopodium; look for movements of the granules in the central portion.

The larger granules within are particles of matter that have been taken in as food through that part of the body with which they first came in contact; there is no mouth, no stomach, but any place on the surface serves as a mouth when a mouth is needed, and any place within serves as a stomach when food is thus taken; neither is there a definite opening for ejecting indigestible matter, but by flowing around the substances it meets, it in a way swallows them, and, having digested and absorbed such parts as are suitable for food, ejects, or rather flows away from the useless remnants.

Make a series of sketches of the outline, at as short intervals as possible, to show the changes of form.

Make also a careful drawing, showing all the parts of the body that have been made out.

The jelly-like substance of which the body of the amœba is composed is **protoplasm.**

The amœba reproduces its kind by simply dividing into two parts, each of which becomes a perfect amœba.

"Thus the amœba **lives, moves, eats, grows, reproduces** its kind, and after a time **dies,** having been during its whole life hardly anything more than a minute lump of protoplasm."

The simplicity of the structure of the amœba and its simple mode of reproduction show its low place in the animal kingdom; with the Vorticella, Paramœcium, and myriads of other microscopic aquatic animals, the Amœba represents the lowest **branch** of the **animal kingdom,** the **Protozoa.** Most of the Protozoa are one-celled animals, in distinction from some of the higher protozoa, which some authors regard as many-celled, and all other animals from sponges to man, which are undoubtedly many-celled.

Thus the simpler Protozoa correspond to the eggs of the higher animals, or the cells of which their bodies are composed.

Many of the protozoans have no hard parts, others have shells; chalk is composed of the shells of certain marine protozoans, a cubic inch of chalk containing as many as 1,000,000 of these skeletons.

"Amœbæ absorb oxygen and give out carbon dioxide and water, and the presence of free oxygen is necessary to their existence. When the medium in which they live is cooled down to the freezing-point, their movements are arrested, but they recover when the temperature is raised. At a temperature of 95° F. their movements are arrested, and they pass into a condition of "heat-stiffening," from which they recover if that temperature is not continued too long; at about 110° F. they are killed.

"Electric shocks of moderate strength cause amœbæ to assume a spherical form, but they recover after a while; strong shocks kill them.

"The amœba is an animal, not because of its contractility or power of locomotion, but because it never becomes enclosed in a cellulose sac, and because it is devoid of the power of manufacturing protein from bodies of a comparatively simple chemical composition. The amœba has to obtain its protein ready made, in which respect it resembles all true animals, and therefore is, like them, in the long run, dependent for its existence upon some form or other of vegetable life."

Since the amœba resembles one of the cells of the higher animals, it is important to fix in mind these **properties** and **modes of life** which are common both to amœbæ and the cells of the higher animals, as thus we

have an explanation of many points in the physiology of man:—

1. The amœba moves; it has the power of contraction or **contractility,** by means of which it accomplishes motion and locomotion.
2. It feels; when any disturbance, such as contact with a foreign body, is brought to bear on an amœba at rest, it moves; this is not because it is pushed or pulled, but is due to its own activity, the contraction of its protoplasm. Any living matter which, when acted on by a stimulus, is excited to activity, is said to be **irritable** (sensitive) in the sense of "susceptible to impression from without."
3. But the amœba does not always wait to be thus stimulated by something external; it moves "of its own accord," as we would say; such action is called **automatic;** the amœba is an individual capable of **spontaneous** and independent activity.
4. The protoplasm of which the body of the amœba is composed is constantly undergoing **chemical change;** this change is of two kinds: one a **wearing out,** depending on the degree of activity, the other a **building up,** to make good the loss. The food is changed so that it is ready to become part of the body; this process is **digestion.** The building of this material into the body is known by the name **assimilation.** The waste products resulting from the breaking up of the old protoplasm are called **excretions,** and are thrown off into the same surrounding medium from which food is taken. All these processes of taking food, digesting and assimilating it, the decomposition

of the body as an accompaniment of activity, and the throwing off of the waste products, are included under the term **nutrition.**

5. The amœba breathes; that is, takes in oxygen and throws off carbon dioxide; this is really a part of the process of nutrition, being most intimately connected with the breaking down of the protoplasm (which invariably accompanies any form of action), during which not only motion, but also heat is produced.
6. The amœba reproduces its kind by simple division into two. Each individual of the higher, many-celled animals develops from an egg, which is a cell, and is essentially like an amœba. As it develops, this cell divides, forming two; each of these divides, and the division continues till many cells are formed; these cells are at first all alike, but soon they grow different from one another, and are arranged in order, forming the various parts of the body; thus one set of cells form **muscle,** another set, developing in a different way, produce the brain and **nerves**; other groups of cells form **bone, skin, cartilage,** etc. Each of these sets of different kinds of cells is called a **tissue**; thus there is **muscular tissue, nervous tissue,** etc. The process of "growing unlike" or **"growing different,"** which the cells undergo in their development, is called **differentiation**; thus, of the cells which were all essentially alike, those of one set have taken one shape, and have acquired certain peculiarities by which they may be recognized, and we say they have become **differentiated** into nervous tissue or muscular tissue, etc.

Now, in the development of higher animals, while all the cells which result from the original cell (egg) are at first essentially alike, not only in structure but in properties, they grow unlike in this latter respect as well; that is, while all the cells have at first in equal measure the properties of **motion, sensation, digestion, respiration, assimilation,** and **reproduction,** each set (tissue) soon develops in a special degree some one of these properties. Take, for instance, the nervous tissue; the cells composing this tissue are regarded as having had originally not only irritability but contractility, and all the other characters enumerated above in describing the amœba; but this kind of tissue has developed, in a high degree, the property of **irritability**, and has lost, in a large measure, the other properties; so the muscular tissue, while it has not wholly lost its irritability, has it feebly developed when compared with nervous tissue, but has the power of **contraction** in a very high degree. Thus each tissue has some one of the general properties in a very marked degree, while the other properties are less apparent, though seldom entirely wanting. All the tissues work together for the common good of the whole animal; all the tissues grow by the increase of the number of their cells, and this is accomplished by the division of the cells; but that division of cells which gives rise to new individuals is limited to the **reproductive tissues.**

Although one set of tissues (the organs of digestion) has the chief work of preparing the food to be built into the tissues of the body, yet each cell must take for itself the food thus prepared for it, and, really, each cell leads an independent life bathed in the liquid part of the blood, which soaks through the walls of the blood-vessels and surrounds every cell; from this liquid nourishment is

taken (or cell starvation follows), and into this surrounding liquid the cell throws its waste products.

In consequence of the complexity of structure, a complicated set of organs is required to circulate this liquid to all parts of the body, so that each cell may be supplied, and to bring air into contact with this current in one part of its course, where oxygen is absorbed for all the cells.

It now becomes evident why one can hold his breath longer after taking several deep breaths, and why distress for breath continues for some time after one has stopped at the end of a foot-race.

The differentiation of cells in the formation of the various tissues of the body may be compared with the division of labor in a community. In a community of savages there is little division of labor; each one, or at least each family, gets and prepares his own food, makes his own clothing, builds his own dwelling (if he has one), and in general supplies all his own wants; in rude communities of more enlightened people the same is very nearly the case. But as time goes on, it is found more advantageous to divide the labor, each devoting himself to one special kind of work; thus each acquires skill in his special line, better articles are produced, and time is saved for all; so, in time, come tailors and butchers, teachers and tanners.

But just in proportion as each individual devotes himself exclusively to one pursuit, he neglects the others, and consequently grows unable to do well in them; that is, by becoming especially fit for one kind of labor, he proportionally unfits himself for others. The grocer does not make his own boots, clothes, hat, house, nor wagon.

In the human body, also, the work is better done by having a special set of cells devoted to a given kind of

work; and the cells of the different tissues, like the individual members of society, by giving themselves entirely to one kind of work, make themselves specially fit for this work, and become almost completely unfitted for anything else.

This is what is meant by the **physiological division of labor.**

Read the descriptions of Amœba in Brooks' "Handbook of Invertebrate Zoölogy," and in "Practical Biology," by Huxley and Martin; the characters of Protozoa, in Packard's "Zoölogy"; the lecture "On a Piece of Chalk," in Huxley's "Lay Sermons, Addresses, and Reviews"; the Introduction to Foster's "Physiology."

THE WHEEL-ANIMALCULE (ROTIFER).

Rotifers are often found in the water of an aquarium where clams and crayfishes have been kept; pick out clusters of plant growth, found in the rubbish and sediment in the aquarium, or on the shells of clams; with a lens look at the walls of the aquarium for small, white, worm-like forms.

The body of the wheel-animalcule is tapering, ending in a two-forked **foot.** At the larger end, when expanded, are two circular **disks,** fringed with cilia; the disks are retractile, as in Vorticella. Between the disks is the mouth; this opens into the **pharynx,** lined with teeth; back of the pharynx are the stomach and intestine.

Rotifers are classed with the worms; though small, the presence of a distinct digestive tube, a distinct nervous

system, and organs of sight and hearing, show the rotifer to be much more highly developed than the protozoans.

Rotifers have been dried and kept for years, and yet when put into water they revived.

Study carefully —

1. The mode of locomotion.
2. The action of the disks and cilia.
3. The motions of the pharynx.
4. The contraction and expansion of the body as a whole.

Make drawings showing the body both in the expanded and in the contracted state.

Read the "General Characters of Rotifers" in Packard's "Zoölogy"; "Rotifera" in Claus and Sedgwick's "Text-Book of Zoölogy."

THE FISH.

Let each pupil have a live minnow in a fruit-jar. Watch the movements of the mouth and gill-covers at the sides of the head. Observe the motions of the eyes. Can a fish wink? Does a fish sleep? Study the action of each fin, trying to discover what work is done by each. What is the chief propelling power? Consider the fitness of the shape of the body for locomotion in water.

THE EXTERNAL FEATURES OF THE FISH.

For this work, and the dissection which follows, the perch is preferable, but bass or croppies serve very well.

Use the dissecting-pan described under "The Crayfish," or put the fish on a large plate.

1. Notice the shape of the fish as a whole; hold the fish, with the belly down and the tail toward you, and observe that there is an **anterior** and a **posterior** part, a **dorsal** and a **ventral** surface, and that it is **bilaterally symmetrical.** A fish whose body is flattened from side to side, is said to be "compressed"; the word "flat," when used in describing a fish, means flattened from above downward, and is applied to such a fish as the flounder.

   Close the mouth of the fish, and measure from the foremost point of the head, the tip of the **snout,** to the front edge, the **base,** of the tail-fin; this is the **length** of the fish. Measure from the tip of the snout to the hinder point of the hard part of the flap which covers the side of the head; this is the length of the **head.** How many times is the length of the head contained in the length of the fish? Measure from above downward at the deepest part; this is the **depth** of the fish. How many times is it contained in the length? Compare the **width** and depth of the fish.

2. The fins on the back are the **dorsal fins**; spread them out to their fullest extent, and study them thoroughly; their framework consists of **fin-rays**; some of them **spinous rays,** or **spines** (unjointed, or **inarticulated**), others **soft rays** (jointed, or **articulated**); study carefully one of the soft rays, using a lens; count each kind of rays; observe the membrane connecting the rays. This membrane is double; the fin is really a fold of the skin, with supporting parts within the fold.

Measure along the base of each fin; this is the **length** of the fin; extend the fin fully, and measure the length of its longest ray; this is the **height** of the fin. Compare the length and height of the fin. In some fishes the dorsal fin is single; in others it is divided, forming two or more dorsal fins.

The tail-fin is the **caudal fin**; when this fin is symmetrical, or nearly so, the backbone apparently ending at the centre of its base, the tail is said to be **homocercal,** as in most fishes; if the backbone extends into the upper lobe of the fin, making this lobe larger, as in the sturgeon, the tail is called **heterocercal.**

The fin in front of and below the caudal, is the **anal** (being just back of the external opening of the intestine, the **anus**); compare this fin with the dorsal.

The fins above named, being in the middle line, are called **median,** or **vertical fins.**

The remaining fins are called **paired fins**; the pair back of the head are the **pectoral fins,** and are considered as representing the forelimbs of the higher animals; the lower pair (usually farther back) are the **ventral fins,** representing the hind limbs of higher animals. Take the ventral fins between the thumb and finger to feel their bony support; rest the fish on its back, and press the thumb and forefinger of the other hand on the bony structures at the bases of the pectoral fins; move the ventrals about to determine, as far as possible by feeling, the relations between the bones supporting the two pairs of fins.

3. Open the mouth of the fish by pulling its lower jaw down as far as possible; the bone which forms the

border of each side of the upper lip is the **pre-maxillary**; note its extension backward on the middle of the snout; observe the fine teeth on it. Observe their size, shape, arrangement, and the direction in which they point.

The paddle-like bone back of the pre-maxillary is the **maxillary.**

The bone on each side of the lower jaw is the **dentary.** Which of these bones bear teeth? Open and shut the mouth repeatedly, watching the movements of these parts, and their relations to each other.

Compare the perch or bass with the sucker in the movements of the mouth parts.

Back of the pre-maxillary, in the front part of the roof of the mouth, is a patch of teeth, borne on a bone called the **vomer**; extending backward from the vomer, on each side of the roof of the mouth, are rows of teeth on the **palatine bones.**

Examine the short **tongue**; feel its surface with the tip of the finger, or scrape it with the head of a pin; examine also the whole of the inside of the mouth, to see if there are more teeth than those mentioned. Can a fish taste?

4. Note the shape and position of the eyes; with the handle of the forceps press on the eye at various points near its margin, to see its range of motion; watch the roof of the mouth while pressing the eye, also press outward on that part of the roof of the mouth nearest to the eye. Compare the eyes with human eyes. Are eyelids present? Observe a thin bone imbedded in the skin immediately in front

of the eyes; it is the **ante-orbital bone.** This and several smaller bones just under the eye are known as **sub-orbital bones.**

5. Examine the **nostrils** in front of the eyes. How many are there? Probe them with a bristle tipped with sealing wax; do they open into the mouth? do any of them communicate with each other?

6. The flap at the side of the head is the gill-cover, and the opening back of it is the **gill-opening.** The upper, hinder piece of the gill-cover is the **opercle;** along its lower posterior border, and rather closely attached to it, is the **sub-opercle;** in front of the opercle, and below and back of the eye, bordering the part known as the **cheek,** is the **pre-opercle.** If the margin of this be toothed, it is said to be **serrate;** under the pre-opercle, and in front of the lower end of the sub-opercle, is the **inter-opercle.**

   The thin membrane below the gill-cover is the **branchiostegal membrane;** the curved bones supporting it are the **branchiostegal rays;** count them. The narrow part of the body between the branchiostegal membranes is the **isthmus.**

7. Raise the gill-cover and examine the **gills:** each gill has a central bony **arch;** on the hind and outer border of this arch is a fringe of red **gill-filaments;** on the front and inner border of the arch are the teeth-like **gill-rakers.** Are these alike on all the gills? A red streak along the arch, at the base of the filaments, is made by the blood-vessels, which bring the blood to, and carry it away from, them.

   Thrust a finger into the mouth, and depress the tongue. What effect has this on the gills? what

effect on the gill-rakers? The slits between the gills, which allow communication from the mouth to the gill-opening, are the **gill-clefts.** How many gills are there? How many gill-clefts? After this study of the gills in their natural position, remove the foremost gill, severing it at its upper and lower ends, and note more fully the parts above named, especially the structure and arrangement of the gill-filaments and gill-rakers; tear away some of the filaments, and find the groove along the posterior, outer border of the bony arch in which run the blood-vessels. Look on the inside of the gill-cover for a red spot — the **false gill.**

8. Observe the arrangement of the scales. Pull out a scale and study its shape and markings, the radiating and concentric **striæ.** Compare its inner and outer surfaces, its anterior and posterior margins; make a drawing of it, naming its parts; pull out a scale from a black spot; compare that part of its surface which was exposed with the part overlapped by other scales; scrape the portion that was exposed; thrust one point of the forceps under the hind edge of a scale, and watch closely this edge, while slowly raising it, to see that a thin skin covers it and passes on to the scale behind. This thin outer skin is chiefly **epidermis.** In this epidermis lie the black **pigment cells** which make the dark spots.

   A scale with a smooth hinder border is a **cycloid scale;** if the hinder portion is toothed or spiny, the scale is **ctenoid.**

9. A raised line along the side is the **lateral line.** Remove one of the scales on this line, and find what makes the line. Is the line continuous?

10. Make a drawing of the fish as seen from one side, naming all the parts visible. Describe fully all the parts above noted, including the general color and markings.

DISSECTION OF A FISH.

Hold the fish with its back in the palm of the left hand, and the tail towards you; thrust the point of one blade of the scissors obliquely forward through the body-wall, just in front of the anus, and cut forward in the middle line to the ventral fins. After observing the organs within, cut upward, *i.e.*, toward the dorsal region of the fish, with scissors, from the beginning of the first cut as far as possible without cutting anything but the body-wall, being especially careful not to cut into the air-bladder which occupies the upper part of the body-cavity; now cut forward to a point a little above the pectoral fin; make the same cut on the other side; turn forward the flaps thus made, noting the silvery membrane, the **peritoneum,** lining these flaps, and study the organs of the body-cavity.

1. In the front part of the body-cavity is a reddish or brownish mass, the **liver,** lying chiefly on the left side of the fish. Raise the hinder edge of the liver, and observe how closely it fits the organs next to it. Press the liver backward, and observe the **hepatic veins** passing forward from the liver through the thin partition in front.
2. Lay the fish on the right side and turn the liver downward, gently tearing away its thread-like attachments. This uncovers a pinkish sac, the **stomach.** Pass a probe back through the mouth and wide

gullet into the stomach, to determine its shape and extent. When the stomach ends blindly behind, the intestine arising from its front end, the stomach is said to be **cæcal.** Compare the stomachs of the perch and sucker. Observe a branch of the **pneumogastric nerve** distributed over this side of the stomach.

3. Find a large tube arising from one side of the stomach, the **intestine.** In many fishes there are at or near this point several worm-like branches, often matted together by fat. Rest the fish on its back, and turn the liver to the left, to examine these. Clear away this fat, separate these tubes and count them. They are **pyloric cæca.** With scissors make a small hole in the end of one cæcum; insert the point of a blowpipe and inflate it.
4. Just beyond the cæca, on the posterior surface of the liver, is a thin-walled sac, of a greenish or yellowish color, the **bile-sac.** When empty, it has a worm-like appearance. Snip it open with the scissors, or prick it with a dissecting needle to see the bile.
5. Trace the intestine to the anus, observing that it is held in place by a thin, transparent membrane, the **mesentery;** observe the blood-vessels in it; tear this away in following the intestine; find a small, deep red body near the intestine, the **spleen.** Compare the length of the intestine in the perch or bass with that of a sucker. The sucker eats vegetable matter, and may be called herbivorous; while the perch and bass feed chiefly on other fishes, and are carnivorous.
6. In the hinder part of the body-cavity are the **reproductive organs;** the yellow **ovary** (varying greatly in size, according to the season) in the female, the

two white **testes** in the male. In some fishes the ovary is single, in others it is double. If double, the two ovaries unite in one tube, which discharges the eggs — the egg-tube, or **oviduct.** Trace the oviduct; has it a separate outlet? Sometimes the eggs in the ovary can be discerned.

7. Back of the oviduct or hinder part of the testes is a small pink sac, the **urinary bladder.** Look for its external opening back of the anus.

8. In the upper part of the body-cavity is the **air-bladder.**

   Make now a drawing of the organs above noted in their natural positions, as seen from below.

   Look closely to see if there is any connection between the air-bladder and the stomach; gently scrape away the thin outer covering, peritoneum, and note its thin wall; examine the whole of this wall to see if there are any blood-vessels in it. After thoroughly examining, puncture and remove it.

9. Above the air-bladder, extending along the roof of the body-cavity are slender, dark red bodies, the **kidneys.** Look for an enlargement of the kidneys in front of the air-bladder; trace one kidney to its posterior termination in the urinary bladder. Cut away all the organs thus far studied, except the kidneys.

10. In front of the liver is a thin partition, the **false diaphragm.** If this is not already opened, cut carefully through it to see the heart; also cut from the anterior end of the first slit in the walls of the abdomen forward to one side of the ventrals, through the bones of the pectoral arch and on through the thick mass of muscle, in the middle line, to the isthmus, and pull

the walls of this cavity, the **pericardial cavity,** out to the sides.

The red, angular portion of the heart, which in the natural position of the fish lies lowest and hindmost, is the **ventricle;** the darker, more irregular portion lying (in the natural position) above the ventricle, is the **auricle;** the larger blood-cavity back of the auricle, and extending across the body-cavity, above the false diaphragm, is the **venous sinus;** in front of the ventricle is the light-colored conical **arterial bulb.** This narrows forward into an artery which gives off branches on both sides, one to each gill. Make a drawing of the heart and arterial bulb. After passing through the gills, the blood-vessels re-unite to form the **dorsal aorta,** which passes backward just underneath the spinal column. From above the gills branches also run forward to the head.

11. Insert the finger into the fish's mouth and depress the tongue. Observe the thin membrane which forms the floor of the mouth on each side of the tongue; cut through this membrane close to the inner border of the lower jaw on each side and across the band of muscle which is attached to the point where the two halves of the lower jaw unite; continue the cut backward on each side between the gill-cover and the branchiostegal membrane, and wholly separate them. Turn back the whole flap thus loosened, and again examine the gills; note the joints in the gills; with the forceps seize the tongue, raise and lower it, to see the action of these joints in the gill-arches.

Observe, where the gills unite above and below, patches of closely set teeth, the **superior** and **inferior**

pharyngeal teeth. The bones supporting these teeth, above and below, are the pharyngeal bones; they represent a fifth gill-arch. Again depress and raise the lower ends of the gills, observing how the pharyngeal teeth are brought together. What is the probable use of these teeth, and what is the work done by the teeth previously examined?

Again examine the gill-rakers, and observe how they are affected by bending and straightening the gill-arches. Examine the bone which bears the branchiostegal rays, and note with what bones it is connected.

12. Examine the bones in the posterior border of the gill-opening; these are together called the **pectoral arch.** The largest of these bones is the **clavicle;** its upper part forms a projection above the base of the pectoral fin. Connected with the upper end of the clavicle is the **supra-clavicle,** which, in turn, is connected with the skull through the **post-temporal.** Cut away the flaps of the body-wall bearing the fins.

13. Note also the bones supporting the ventral fins; these are considered as representing the **pelvis.** In the higher fishes the pelvis is fastened to the clavicle; in the lower fishes it is separate from the rest of the skeleton and imbedded in the flesh. How is it in the specimen you are studying? Carefully remove the ventrals, with the bones which support them; examine and describe them, after scraping away all muscles and other soft tissues.

If the dissection of the muscles and the brain are not to be made at this time, carefully cut away the gills at their upper attachment, and remove them;

wash the fish thoroughly, wipe it dry, and keep it in a cool place.

14. Hold the fish in the left hand, with its back up and its head away from you; insert the point of one blade of the scissors at the base of the caudal fin and cut the skin forward, passing to the left of the dorsal fin and on to the head; remove the skin of this side, carefully leaving the white muscles beneath undisturbed; scrape part of the skin clean on the inside; note the arrangement of the scales as seen on each side of the skin; look also for traces of the lateral line on the inside of the skin. Hold the skin up and look through it toward the light, alternately stretching and shortening it, noting especially the lateral line. Roll the skin lengthwise, with the scales outermost, to see how the epidermis passes from one scale to another.

15. Observe the parallel, transverse markings on the muscles along the body.

16. Cut and scrape away all the muscle of this side of the body down to the bones, and make out the central backbone, with its bony projections above and below. Bend the dorsal and anal fins from side to side, to show the bones which support these fins and the relation of these fin-supporters to the projections of the backbone.

17. Break across the backbone under the centre of the second dorsal fin, and remove one of the pieces, or **vertebræ**, of the backbone; clear away all muscle and other tissue, and make out the following parts: —

   a. The central body, or **centrum**, shaped like an hour-glass, and hollowed at each end.

b. Two projections extending upward, soon uniting to form one spine, the **neural spine.**

c. The archway formed above the body of the vertebra is the **neural arch.**

d. A similar arrangement below, forming the **hæmal arch** and **hæmal spine.**

Make a drawing of this vertebra as seen from the side; as seen from the front.

18. In like manner remove and study a vertebra from a point opposite the centre of the first dorsal fin, with the ribs attached to it. What are the differences between these two vertebræ?
19. Thoroughly clean the last vertebra, and study carefully its relations to the caudal fin.
20. Observe the white **spinal cord** in the canal formed by the neural arches above the bodies of the vertebræ. This is the nerve-canal, or **neural canal**; note also the blood-vessels in the corresponding blood-canal, or **hæmal canal,** below.

THE BRAIN OF THE FISH.

Cut off the head; clear away the muscles at the back of the head; carefully slice off the top of the skull with a strong, sharp knife; with extreme care cut away the roof of the brain-cavity; a mass of loose, gray tissue covers the brain, which is of a white or pinkish color; cautiously pick away this loose tissue, using a small syringe to wash away the loosened matter. Make out the following parts of the brain, beginning at the posterior end:—

1. The cut-off end of the spinal cord.
2. The widened part of the spinal cord, where it passes

under the hinder part of the brain, is the **medulla oblongata.**

3. The hinder, undivided part of the brain is the **cerebellum.**
4. In front of the cerebellum are the two large, rounded **optic lobes,** forming the widest part of the brain.
5. In front of the optic lobes are two oval masses which meet in the middle line; these are the **cerebral hemispheres,** and together they constitute the **cerebrum.**
6. Observe the **olfactory lobes** tapering forward in front of the cerebral hemispheres; from these trace the **olfactory nerves** to the nasal cavities.

Make a drawing of the brain as seen from above, naming all these parts. Cut open one of the optic lobes and note that it is hollow; push the eyes outward and find a white cord extending inward and backward from each. These are the **optic nerves.**

THE MUSCLES OF THE EYE.

1. Cut away the upper part of the eye-sockets and find in each a muscle extending outward and backward from the anterior part of the socket to the top of the eyeball. This is the **superior oblique muscle.**
2. Another muscle coming from the posterior part of the socket will be seen passing forward to be attached under the oblique muscle. This is the **superior rectus.** Make a drawing showing these muscles. The other eye-muscles may be more easily examined from beneath.

If the under surface of the skull of the specimen previously studied be not injured, it may be used; otherwise, cut off the head of another fish, and cut

away completely the lower jaw and the floor of the mouth. Move the gill-covers in and out to show more clearly the thin plates of cartilage between the eyes and the roof of the mouth; with scissors slit in the middle line the tough membrane lining the roof of the mouth, and strip it out to the sides. Observe a muscle running outward from each side of the base of the skull to the corresponding gill-cover. Cut these at their inner ends and turn them outward. With scissors cut away the cartilages covering the under surfaces of the eyes.

3. Observe a muscle passing outward from the front part of the socket to the eyeball, the **inferior oblique muscle.**
4. The muscle running forward close to the partition between the eyes is the **internal rectus.**
5. On the under surface of the eye is the **inferior rectus.**
6. Attached to the hinder border of the eye is the larger **external rectus.** Note carefully the origin of each of these, their place of insertion on the eyeball, and their change of shape in their course; consider the effect of each on the eye.

Observe the thin-walled swellings at the sides of the base of the hinder part of the skull; cut into these **ear-capsules** and find in each a membranous sac, the **vestibule** of the ear. In this sac lies the "ear-bone" or **otolith.** Find the white optic nerve arising from the inner surface of the eyeball; with a sharp knife cautiously cut away the base of the skull and trace the optic nerves to the brain; demonstrate that they cross each other, the optic nerve from the right eye entering the left half of the brain, and *vice versa.*

Make a drawing showing this view of the brain and eyes; open one of the eyes and remove the spherical crystalline lens.

The air-bladder (sometimes called the swim-bladder) is believed to be of use to the fish in keeping its place in the water. In many fishes the air-bladder is connected with the œsophagus by a tube, and in many others there is a circulation of blood in part of the wall of the air-bladder. The air-bladder really corresponds to the lungs of the higher animals.

Parts of animals having essentially the same structure, or corresponding in origin, are said to be **homologous.** Thus the air-bladder of the fish and the lung of the snake are homologous. The pectoral fins are homologous with the fore limbs of the higher animals, and the hind limbs of the higher animals are the **homologues** of the ventral fins of the fish. Parts which are alike in use are said to be **analogous.** Thus the gill of a fish and the lung of a man are analogous; both serve in getting oxygen into the blood.

Analogy is correspondence in use or **function.**

Homology is correspondence in structure or **origin.**

In some fishes the air-bladder is actually used as a lung. These fishes are in consequence called **lung-fishes.** Some of our fishes which breathe by gills have the power of living out of water for some time, and are said to crawl from one body of water to another when the former dries up.

Fishes are the lowest of the vertebrates; they are also the oldest of vertebrates, in the order of their appearance on the earth.

The young fishes of all kinds have heterocercal tails, but as they grow older, the higher fishes develop homocercal tails. The earliest fishes had heterocercal tails, as have many of the lower fishes at the present day.

Again, the early fishes had cartilaginous instead of bony skeletons. All young fishes have cartilaginous skeletons, but the higher fishes develop bone in place of cartilage as they grow older.

It will be seen then that the stages of development of the higher fishes repeat the order of the geologic appearance of fishes, and review the classification of fishes from the lowest to the highest. What do these facts signify?

Use Jordan's "Manual of the Vertebrates" (latest edition), or, better, Jordan and Gilbert's "Synopsis of the Fishes of North America," for finding the names of fishes as "Gray's Manual" is used for "analyzing" plants.

THE FROG.

In the spring frogs gather in ponds and streams to breed. Later, they may be found in meadows and fields near water. When seeking them in such places walk rapidly along so as to frighten and make them jump so they can be seen. When studying frogs it is well to get a good supply and keep them alive in a box, which should be shut securely, leaving a few holes. This box may be kept in a cellar or in a watering-trough. Frogs will live a long time without feeding. In capturing frogs observe how they dive into the mud to escape.

STUDY OF THE LIVE FROG.

1. Put a live frog into a tub of water and study carefully its mode of swimming and floating.
2. Notice how the frog sits when at rest.
3. What has the frog in common with other animals that jump well?
4. Watch closely the frog's breathing, paying especial attention to the throat, nostrils, and sides.
5. Touch the eyeball with a pencil, and note what follows.
6. Note the motions of the eyelids.
7. What does the frog eat, and how does it take its food?
8. Look for slight pulsations near the end of the backbone on each side, near the anus. These are the beatings of the **lymph-hearts.**

   Make drawings of the live frog in the sitting posture.

EXTERNAL FEATURES OF THE FROG.

Kill a frog by wrapping it in a towel or piece of cloth of any kind, and moistening the latter with chloroform; or put a teaspoonful of ether in a fruit-jar nearly full of water, immerse the frog in it, and cap the jar.

1. Has the frog a neck? Find the division between the head and the body by bending the parts and feeling for the joint.
2. Back of and below each eye is an oval area, the membrane of the ear-drum, or **tympanum.**

3. The fore limb consists of the **arm, forearm, and hand.**
4. The hind limb consists of the **thigh, leg, and foot.**
5. Count the fingers and toes.
6. What differences are there between the fore and hind limbs?
7. Open the mouth, seize the tongue with the forceps and draw it forward; observe that it is attached in front, but free behind. How is such a tongue used?
8. Look closely for teeth. Where are they?
9. Pass a bristle tipped with sealing-wax into one of the nostrils. Where does it enter the mouth?
10. Make a small opening in one of the tympanic membranes, pass a bristle through this opening, and look for its appearance in the mouth. The opening through which it appears is the **Eustachian tube.**
11. The mouth narrows back into the gullet.
12. In the back part of the floor of the mouth is a small slit, the **glottis,** leading to the lungs.
13. Compare the colors and markings of the upper and lower surfaces of the frog; draw dorsal and ventral views of the dead specimen, naming all visible parts.

INTERNAL STRUCTURE OF THE FROG.

1. Cut through the skin of the abdominal wall along the middle line; turn the skin back on each side, noting how loosely it is attached to the abdominal wall. Cautiously avoiding any large blood-vessels, open the abdomen lengthwise from the pelvis to the breast-bone; from the hinder end of this slit cut outward on

each side and turn back the flaps so as to expose the internal organs; with forceps raise the hinder part of the breastbone; observe the heart lying next it, and a thin membrane extending from it to the breastbone; with scissors cut this membrane close to the breastbone; cut through the breastbone in the middle line, and stretch its parts well out to the sides to disclose the heart and surrounding organs. Lay the frog on its back; stretch the fore limbs out to their fullest extent, and pin them down.

2. Insert the blowpipe into the mouth and inflate the stomach. Study its shape.
3. Trace the intestine from the stomach to the anus.
4. An enlargement of the intestine near the anus is the **cloaca.**
5. The thin membrane which attaches the intestine to the back of the abdomen is the **mesentery.** In a freshly killed specimen blood-vessels may be seen in the mesentery. Trace these blood-vessels.
6. The dark liver partly covers the stomach.
7. Between the lobes of the liver is the greenish **bile-sac.**
8. In the mesentery, near the stomach, is the pale **pancreas.**
9. Further back in the mesentery is the small red **spleen.**
10. If the previous inflation did not reveal the large **urinary bladder,** insert the blowpipe into the anus, and inflate the bladder through the cloaca.
11. In the female, masses of dark, spherical **eggs** may be seen. The eggs are in the **ovary,** which is very large when full of eggs, and much folded and plaited.
12. The egg-tube, or **oviduct,** is a long, coiled tube running back to open into the cloaca. Cut a small hole in the

oviduct near its anterior end and insert a bristle tipped with sealing-wax to discover where the oviduct terminates anteriorly, and with what it connects at this end.

13. In the male, the yellowish **testis** corresponds to the ovary.
14. Connected with the ovary or testis are usually found slender masses of fat.
15. The **kidneys** are two long, deep red bodies alongside the backbone, in the hind part of the body near the cloaca.
16. Insert a blowpipe through the mouth into the glottis and inflate the **lungs**; observe their shape, and that they are nearly hollow sacs, not spongy all the way through as in the lungs of the rabbit or man. When a lung has but few cells, only a small quantity of blood can come into contact with the air. Such a lung is adapted to an animal of low temperature and sluggish habits. Tie a thread around each lung while it is inflated; cut the lungs out and hang them up to dry thus expanded. When thoroughly dried, they may be cut open and compared with the lungs of a turtle similarly prepared.
17. The thin sac inclosing the heart is the **pericardium**. Carefully cut it away; time the pulsations as seen in a freshly killed specimen. What is the effect of applying gentle heat to the heart, as by breathing on it? The hinder conical part of the heart is the **ventricle**; farther forward and nearer the back are the **auricles**; running forward from the ventricle is the main artery. This divides into two branches, each of which has three subdivisions: —

a. To the head, the **carotid.**

b. To the body generally, the **aorta.** Trace the two aortæ, right and left, to their point of union near the spleen.

c. To the lungs and skin, the **pulmo-cutaneous.**

Part of the impure blood is sent to the skin, through which it gets oxygen. In this way the frog gets oxygen when under water for a long time, and during the winter, when it hibernates deep down in the mud. Remove the heart. Does it beat after removal from the body? Note the effect of holding the heart in the palm of the hand. Note the effect of pricking it with a needle.

CIRCULATION OF BLOOD IN THE WEB OF A FROG'S FOOT.

Split a cigar-box cover or shingle in the middle, and cut a V-shaped notch in one end; wrap the frog in a wet cloth, with one leg projecting, and tie it thus wrapped to the board; tie threads around two of the toes, and stretch the web (but not too tightly) over the V-shaped notch; place the board firmly on the stage of the microscope. Examine first with a one-inch objective. The large vessels which grow smaller by subdivision are the **arteries.** The large vessels which are formed by the union of smaller ones are the **veins.** The finer vessels forming a network are the **capillaries;** the black spots are **pigment cells.** Where these are very abundant, they make dark spots, as seen on the frog's back. Take a triangular piece of cover-glass a little smaller than the web under examination; place a small drop of water on one side of it, and lay the glass, with the water downwards, on the web. Put on a

higher power, say a quarter-inch objective, and study the little bodies floating in the blood. These are the **corpuscles.**

1. The large, faintly colored oval corpuscles; do they change their shape when pressed, as in turning a corner? What is the color of these corpuscles? Mould a bit of clay into the shape of one of these bodies.
2. The smaller, rounded, paler corpuscles, fewer in number and moving with a slower and more unsteady motion along the sides of the channel; what must be the shape of these? Place a drop of frog's blood on a slide, cover with a cover-slip, and examine with a high power. Make careful drawings of the two kinds of corpuscles. (Take a small drop of blood for this, and after covering it, run a little oil around the edge of the cover to prevent drying.)

THE NERVOUS SYSTEM OF THE FROG.

The nervous system is better seen in alcoholic specimens. Slit the skin along the back from the snout to the anus; with a sharp knife cautiously cut away the top of the skull, and find:—

1. Between the eyes, side by side, two elongated white bodies, the two halves, or **hemispheres,** of the **cerebrum.** Observe two small pear-shaped bodies, the **olfactory lobes,** in front of the cerebral hemispheres. These taper forward into nerves running to the nasal region; these are the nerves of smell, or **olfactory nerves.**
2. Back of the cerebral hemispheres are the **optic lobes,** forming the widest part of the brain. Prove that a

white cord, the **optic nerve,** connects each of these lobes with one of the eyes; does the optic nerve extend directly from each eye to the corresponding optic lobe?

3. Extending backward from the under side of the optic lobes is the **medulla oblongata.**
4. The medulla oblongata narrows and becomes the **spinal cord.** Trace the spinal cord back into the spinal column, cutting away the part of the backbone that covers it.
5. In the middle of the body-cavity find nerves emerging from the sides of the spinal column, hence called the **spinal nerves.** Find that several of these, after running backward, unite to form one large nerve. Trace the nerve down between the muscles of the thigh; this is the **sciatic nerve.**

REFLEX ACTION OF THE FROG'S SPINAL CORD.

Take a live frog, and find, by bending the head, the joint between the head and the backbone; lay the frog on a board, and quickly thrust the blade of a knife through the body at this joint, and completely sever the spinal column and spinal cord. This destroys sensibility, and is essentially the same as cutting off the head. After severing the cord back of the head, run a wire into the brain-cavity and stir it about in order to entirely destroy the brain. In a few minutes hang the frog by a hook through the jaw.

1. Pinch the toes; what follows? Repeat the experiment several times. Pinch the skin near the anus.
2. Slit the skin along the back side of the thigh; tear

apart the muscles, and find the sciatic nerve; with a sharp pair of scissors (while watching closely the foot) sever this nerve; what takes place?

3. Hang up as before, and pinch the toes of each foot; what difference is now observed?
4. With the forceps alternately pinch the two ends of the severed sciatic nerve; what takes place as these two ends are pinched?
5. Run a wire down the spinal column, twisting it about to destroy the spinal cord; what occurs while this is doing?
6. Pinch the toes as before; what results?
7. Again pinch the end of the sciatic nerve, still connected with the parts below, being careful to pinch a little lower than before.

THE FROG'S MUSCLES.

Make a circular cut through the skin at the top of the thighs, and pull off the skin of the hind limbs like a pair of hose. Notice the pale color of the muscles. The muscles of the frog's thigh are nearly the same in number and arrangement as in man. Notice especially the calf-muscle; the end by which it is attached above, the less movable end, is its **origin.** The muscle tapers into a strong, white **tendon** below. The end of the muscle at its more movable end (or its attachment by a tendon at its more movable end) is its **insertion.**

Observe the thin, transparent membrane covering the muscle, the **muscle-sheath.** Tear the muscle to pieces, and note its fibrous structure. Put a bit of the muscle in a drop of water on a slide, and cover with a cover-slip;

examine first with a low, and then with a high power, to see the cross-markings of its finest fibres. This kind of muscle is called **striped** or **striated.**

THE ACTION OF A FROG'S MUSCLE.

Entirely remove the skin from one of the frog's hind limbs; sever the limb from the body at the hip-joint; clear away all the muscles of the thigh, carefully preserving the sciatic nerve, still connected with the leg below; sever the heel-cord below the heel, and separate the calf-muscle from the other muscles of the leg, leaving undisturbed its attachment above; just below the knee, cut away the shin-bone, with all the muscles of the leg, except the calf-muscle; there should now remain the thigh-bone, with the lower part of the sciatic nerve running to the calf-muscle suspended below; tie a string around the thigh-bone, and suspend the whole; hang a slight weight, such as a door-key or a pair of scissors, to the tendon at the lower end of the muscle; now pinch the upper end of the sciatic nerve, meanwhile closely watching the muscle.

THE FROG'S SKELETON.

Clean the skeleton of the frog after dissection. This is easier after soaking it in water for a few days.

1. Note how open and light the skull is, and how easily the bones are cut.
2. Count the parts of the spinal column; these are the **vertebræ.** The long bone terminating the spinal column is the **urostyle.**
3. Observe the long bones of the **pelvis,** parallel with the urostyle. What makes the frog hump-backed?

4. The fore limb has, in the upper-arm, the **humerus**; in the forearm the **radius** (same side as the thumb) and the **ulna**; in the wrist are several small bones, the whole collectively called the **carpus**; in the hand are the **digits.**
5. The hind limb has, in the thigh, the **femur**; in the leg, a bone which shows, by grooves near its ends, that it is formed by the union of two bones corresponding to the **tibia** and **fibula** of man; the several small bones of the ankle are together called the **tarsus**; the bones of the toes are the **digits.**
6. Are there any ribs?

THE DEVELOPMENT OF THE FROG.

By wading into a pond where there are frogs, in the spring, one can usually see how the eggs are laid. If these eggs are watched, they will be seen to produce tadpoles; the tadpoles may be reared; at first the form is fish-like, not only in external form, but in the fact that the tadpole has no lungs, but breathes by gills. An opening may be seen on one side, through which water reaches the gills. Later, the lungs develop, and the gills disappear. How do the gills of a tadpole compare with those of a fish? Is the tadpole a fish?

Put a small tadpole in a watch-crystal containing water; examine the gills under a one-inch objective to see the circulation of the blood through them. Has the tadpole teeth? Examine its mouth; what does the tadpole eat? Open a large tadpole, and observe the long, coiled intestine.

THE FROG'S RELATIVES.

Frogs, with toads and salamanders, belong to that class of vertebrates called **Batrachia.** What are the points of difference between frogs and toads? "The toad is exceedingly useful as a destroyer of noxious insects. It is nocturnal in its habits, is harmless, and can be taken up with impunity, though it gives out an acrid fluid from its skin, which may poison the eyelids."

How does a tree-toad differ from a common toad? Should we say tree-toad, or tree-frog? Take a tree-toad from green leaves, and put it into a white-lined box; cover the box with a pane of glass. Is the tree-toad's color affected by this change of surroundings?

Salamanders are often found in cellars, and under rotten logs, and in springs. They are often wrongly called lizards. Lizards are scaly, and are true reptiles, and are related more nearly to the snakes aud turtles. Salamanders have smooth bodies; they are harmless (as also are lizards). If you find one, examine it carefully. Salamanders also develop from a tadpole stage. Some salamanders are viviparous. If kept in the dark, they sometimes fail to complete their development. The mud-puppy, a large salamander found in our rivers, retains its gills through life.

The frogs and toads (tailless Batrachia) rank higher than the salamanders (tailed Batrachia), having passed through the salamander stage and gone on to a higher, in which they have more perfect organs.

In studying insects, we observed that insects pass through a worm-like stage, and that they rank higher than worms.

Geology tells us, from the remains found in the rocks, that most of the animals now living are different from those of early ages.

The earlier Batrachians were tailed; they were salamander-like; the frogs and toads appeared later. Thus the different stages of development of the frog repeat the order of appearance of Batrachia in geologic succession, and review the classification of Batrachia from the lowest to the highest.

EXTERNAL FEATURES OF THE SNAKE.

Examine the scales; observe their relation to each other and to the skin. A scale having a ridge running lengthwise in the middle line is **carinated**; if there be no such ridge, the scale is called **smooth.** How many rows of scales are there, not counting the wide plates below?

These wide plates along the belly, as far back as the anus, are the **gastrosteges**; count them. The plate immediately in front of the anus is the **anal plate**; if it is of one piece, it is called **entire**; if of two pieces, it is **bifid.** The plates under the tail are the **urosteges**; how do they differ from the gastrosteges? count them. Why should there be these large plates below instead of the smaller scales found on the upper surface?

Keep a live snake, and watch its breathing movements. Does the interval of rest occur after breathing in or after breathing out? Touch the eyeball with a stick; can the snake wink? Watch the movements of the tongue.

DISSECTION OF THE SNAKE.

For dissection get a large specimen ; a live one is better, as after severing the spinal cord at the neck (which is essentially the same as cutting off the head), the beating of the heart may be seen, and the persistent vitality of the nerves and muscles serve well to illustrate reflex action of the spinal cord. Lay the snake's head on a board, and with a knife cut entirely through the spinal column, just back of the head; but do not cut off the head. This destroys its sensibility. Get a paper of tacks, and a board as long as the snake. Lay the snake on its back, with the head at one end of the board. Push the point of a tack into the mouth at one side, and drive it through the upper jaw, leaving the lower jaw free. Repeat with the other side. Stretch the snake out straight, and tack through the tail, just back of the vent. With the forceps pinch up a fold of the skin of the throat, and cut through it with the scissors; continue the cut back along the middle line of the belly, being very careful not to cut anything within. As the cut proceeds, stretch the skin out at the sides, and tack it down every two or three inches. Cut away the thin membrane which extends across from the ribs on each side, avoiding blood-vessels.

1. With forceps seize the lower jaw and pull the mouth open. Note how dilatable the mouth is, and how loosely the lower jaw is hinged to the upper; note, also, that the right and left halves of the jaws do not unite in front. Examine closely the **teeth,** their shape and arrangement.

2. Seize the **tongue,** and draw it forward from its sheath in the floor of the mouth. Observe its black, forked tip; tack it down.
3. Above the tongue find a small opening, the entrance to the windpipe. It is called the **glottis.**
4. Insert a blowpipe (glass tube) into the throat through the mouth; pinch the walls of the gullet closely around the blowpipe, and inflate the wide **gullet** and **stomach.** What does the snake eat, and how does he eat?
5. For inflating the lung, a tube with a small point is better; draw out a small glass tube, and connect with a rubber tube; insert the point in the glottis, and inflate. This locates the pink **lung,** with its posterior, thin walled extension, or air-sac.
6. Trace, from the glottis to the lung, the ringed windpipe, or **trachea.** Only one lung is developed; look for the rudiment of the other.
7. The heart will be noticed on account of its beating; the part of it farthest from the head is the **ventricle;** nearer the head find two parts, the right and left **auricles.** These two contract at the same time, just before the contraction of the ventricle. The heart is in a thin sac, the **pericardium;** pinch up a fold of this with the forceps, and cut through it, and remove that part of it covering the heart, very carefully avoiding blood-vessels.
8. Find a blood-vessel arising from the ventricle just between the auricles, and passing forward between them, curving around over the gullet to the posterior part of the body. This is the main artery, or **aorta;** look for its branches running to the head.

9. Look also for an artery running to the lung, the **pulmonary** artery.
10. Find several **veins,** of a darker color than the arteries, leading to the heart.
11. Alongside the stomach is a dark red body, the **liver;** a large vein runs along its surface.
12. Back of the liver is the dark **bile-sac,** and near this the spherical red **spleen.**
13. Clear away any masses of fat that may hide organs in the posterior part of the body, and again inflate the stomach and lung for a more perfect view of these organs.
14. Trace the **intestine** from the hinder end of the stomach to the opening, the **anus,** at its posterior end.
15. In the hinder part of the body-cavity may be found the reproductive organs, **ovaries** in the female, **testes** in the male. These both have long tubes, extending backward to convey their contents to the posterior, dilated portion, the **cloaca,** of the intestine.
16. Into the cloaca also open the ducts of the **kidneys,** two reddish, elongated structures.
17. Count the ribs of one side.
18. Draw the points of the forceps quickly along the muscles over the ribs; note the contraction of the muscles that follows; such contraction of the muscles is wholly involuntary (as the brain now has no connection with the body), and is called **reflex action of the spinal cord.** It is the same kind of action as that seen in the case of a chicken with its head cut off.

Use "Jordan's Manual of the Vertebrates" for finding the names of snakes.

THE TURTLE.

1. The upper part of the shell is the **carapace.**
2. The under part is the **plastron.**
3. Observe the large sections, or **plates,** marking the shell. How many of these plates are there on the carapace? how many on the plastron? how are they arranged?
4. Study the motions of the head, legs, and tail; observe the **scales** on these parts.
5. Note the shape of the feet; for how many purposes does the turtle use its feet? are the feet of all turtles alike? Count the claws; compare the front and hind feet.
6. With a strong pair of pinchers seize the head, pull it well out, and chop it off; examine the mouth; are teeth present? Is there a tongue? Look for a third eyelid. Compare with the pigeon in this point of structure.

DISSECTION OF THE TURTLE.

Saw through, or cut with a strong chisel, the bridge which connects the carapace and plastron on each side. Carefully raise the plastron, and, keeping the blade of the knife or scalpel close to its inner surface, cut away all its attachments to the organs within, and remove it entirely.

1. In front are the bones supporting the fore limbs.
2. Behind are the bones of the **pelvis,** supporting the hind limbs. Were these two sets of bones attached to the plastron?

3. A thin membrane covers the internal organs; through it the **heart** may be seen beating. Cautiously avoiding blood-vessels, cut away this thin covering, and distinguish the following parts of the heart:—

   a. The large, hinder part, the **ventricle.**

   b. In front, on each side, the two **auricles.**

   c. Between the auricles are blood-vessels, branching toward the head. As in the frog, there are two aortæ, the right and left, which unite posteriorly.

4. Make out the following order of the heart's beat:—

   a. The contraction of the blood-vessels leading to the auricles.

   b. The contraction of the auricles.

   c. The contraction of the ventricle.

5. On each side of the heart appears the dark **liver**, consisting of two main lobes, connected by a cross-band. Search the liver to find the **bile-sac.**
6. Under the left lobe of the liver is the **stomach.**
7. From the stomach trace the intestine to the transverse vent under the tail.
8. Masses of eggs may be found in the **ovary** (if a female).
9. Find a large bladder near the pelvis.
10. Raise the liver to find the **lungs**; pull forward the neck, find the windpipe, and insert a blowpipe. By inflating, the lungs may be better seen. When the lungs are fully inflated, tie a string tightly around the windpipe; carefully remove the lungs, and hang them up to dry. When they are thoroughly dry and firm, cut them across, and compare with the lungs of the frog and rabbit.

11. How does the turtle draw in its head?
12. How long does the heart beat after the head is cut off?

THE SKELETON OF THE TURTLE.

1. Clean away the muscles and all soft parts. Boiling loosens the outer plates; these are part of the skin, and not of the skeleton proper; they are called the **epidermal plates.**
2. When these plates are removed from the carapace, there appears a series of bones extending outward on each side; these are the ribs, very wide, and united by their edges. How many of these flattened ribs are there?
3. On looking at the inner surface of the carapace, the series of **vertebræ** will be found; and attached to the sides of the bodies of these vertebræ are the heads of the ribs.
4. Along the middle line of the outside of the carapace between the ribs of the two sides, is found a series of bony plates; these are the enlarged and flattened projections of the vertebræ; they correspond to the spines which make the sharp ridge along the backs of most vertebrates.
5. Compare the bones of the pelvis and of the limbs with those of the rabbit.

For a full account of the anatomy of a turtle, see "How to Dissect a Chelonian," by Prof. H. N. Martin and Dr. W. A. Moale.

For finding the names and classification of turtles, use Jordan's "Manual of the Vertebrates."

THE PIGEON.

If possible, capture the pigeons alive, and kill them in the following manner: Open the pigeon's mouth and insert a pipette containing about a teaspoonful of chloroform into the opening of the glottis, at the base of the tongue; blow the chloroform into the lungs, being careful that the point of the pipette does not slip out of the glottis. If the pigeons are taken alive, it is a good plan to keep them fasting for a day, that their crops may become empty.

Note the shape of the body as a whole, and its adaptation to rapid passage through the air.

THE HEAD.

1. The **beak** consists of the upper and lower **mandibles**; hold the pigeon's head with one hand, and with the other take hold of the tip of the upper mandible and prove that it is movable.
2. Raise the upper eyelid, and look in the front angle of the eye for the third eyelid; seize the edge of this with the forceps, and pull it backward over the eye. Watch the live bird, to see how it winks.
3. Brush forward the feathers below and back of the eye to find the **ear-opening**; observe the peculiarities of the feathers which cover this opening.
4. Examine the **nostrils**; open the mouth and insert the head of a pin into the nostril, and probe, to discover its place of appearance in the mouth.

5. With the forceps pull forward the **tongue** for careful examination.
6. Just back of the tongue is the opening, the **glottis,** of the **windpipe,** or **trachea.**
7. The mouth continues backward to become the gullet.

THE WINGS.

1. Feel of the wing to make out the division into **arm, forearm,** and **hand.**
2. The foremost angle of the wing is called **the bend of the wing.** To what part of your arm does this bend of the wing correspond? Just outside of the bend of the wing find the **false wing,** a cluster of short quills, borne on the **thumb.**
3. The long **quills** borne on the hand are the **primaries;** count them. The quills on the forearm are the **secondaries;** count them. When quills are found on the arm, they are called **tertiaries.**
4. The shorter feathers which overlap these quills above and below, are the upper and lower **wing-coverts.**
5. Extend the wing; compare its upper and lower surfaces; observe the shape of the quills, and the way they overlap one another; put all these facts together and consider their effect in the down-stroke of the wing. What is the result of this arrangement when the wing is moved quickly upward?

THE LEGS.

1. Feel of the parts, beginning close to the body, to be sure to find the first division of the limb; this is the **thigh,** or **second joint.**

2. Below this is the **leg proper,** or **drumstick.**
3. The next division is the **tarsus;** it is a consolidation of several bones that were distinct in the young bird; this part of the bird's leg, then, really corresponds to the tarsus and metatarsus of the human foot, or that part between the ankle and the toes. Where, then, is the true heel?
4. Bend and extend the **toes** to find how many bones there are in each.
5. The scales on the front of the tarsus are called **scutella;** hence the tarsus of the pigeon is said to be **scutellate** in front; the back of the tarsus of the pigeon is **reticulated.**

THE TAIL.

1. Count the quills of the tail; spread the tail to see their mode of overlapping; make a diagram to show their mode of overlapping as seen from behind; compare the middle and outer tail-feathers.
2. The feathers which lap over the base of the tail are the upper and lower **tail-coverts.**
3. Raise the upper tail-coverts, to find the conical tip of the outlet of the oil-gland; press the oil-gland to get a drop of oil.
4. In front of the lower tail-coverts is the **anus.**

THE FEATHERS.

1. Pull out one of the large wing-quills and study its parts; the central axis is the **shaft;** the expanded part is the **vane;** the side branches of the shaft are the **barbs,** and the side branches of the barbs are the

barbules. With a lens examine the upper and lower surfaces of the vane; then tear one of the barbs loose from the barbs in front of and behind it, and study it carefully; again watch closely while tearing two barbs apart, to see how the barbules are related to each other; now examine the vane of the same quill at the very beginning of the vane, near the end that was attached to the wing. What is the difference between the arrangement of the barbs in these two places? Observe the hole in the tip of the shaft; run the point of a dissecting-needle along the groove in the under surface of the shaft toward the base of the shaft. This should lead the point of the needle into another opening, communicating with the cavity of the shaft. Examine this region with a lens, and determine that the two sides of the vane meet at this point. Make drawings of a quill, as seen from above and below, showing all these points.

With sharp scissors cut across the middle of the quill. Look at the cut end; observe that the vane is attached to the **upper edges** of the shaft; compare the place of attachment of the vane to the shaft, with the place of attachment of the wing to the body. Cut part of the wider side of the vane, at right angles to the barbs; with a lens, or a low power of the microscope, examine the edge of this cut. Make drawings showing these arrangements of the parts of the quill. What are the advantages of such arrangement?

2. Take one of the body-feathers, and compare it with the quill. In what lies the chief difference?
3. Find a feather that is wholly composed of "down," if

there be such; examine the "down" with a microscope.

4. Pick a small part of the breast, and study one of the **pin-feathers.** How does it differ from the feathers already examined?
5. Feathers correspond to the hairs of mammals; there are muscles in the skin of the pigeon, by the action of which the feathers may be raised, as when the bird is angry, or when taking a dust-bath, just as there are muscles in the skin of a dog or cat, or in the human scalp, by which the hair is made to stand on end.
6. Study the arrangement of the feathers; do feathers grow on all parts of the body? a fledgling shows this point well. Push aside the feathers along the line of the ridge of the pigeon's breastbone and examine the skin; do feathers grow here? Look for other unfeathered areas. Note how the feathers overlap.
7. Pick the feathers from one side of the pigeon, just to the middle line; lay the bird on the feathered side, and make a drawing, showing (1) the outline of the feathers; and (2) the outline of the body within.

DISSECTION OF THE PIGEON.

Pluck the pigeon before dissecting it; dipping the bird in hot water makes this easier.

1. Insert a tube into the mouth and inflate the **crop,** compressing the neck to prevent the escape of the air. Note the shape of the crop.
2. Beginning at the posterior end of the breastbone, cut

through the skin along the line of the ridge, or keel, of this bone, and loosen the skin on each side, continuing forward over the crop, being careful not to tear the crop; again inflate the crop, and examine it more fully. Observe the fine lines running crosswise and lengthwise in the walls of the crop; these are the muscle-fibers, transverse and longitudinal. Glands in the lining of the crop secrete a milky liquid, in the breeding season, to act on the food and soften it; this softened food is brought up from the crop and put into the mouths of the young pigeons.

3. Loosen the crop from the front of the breast and from the neck.
4. Find the windpipe, or **trachea,** with its white rings of cartilage.
5. On each side of the neck is a vein and a white cord, the **pneumogastric nerve;** the vein is the **jugular vein.** If it does not show distinctly, let the bird's head and neck hang over the edge of the table, and the vein will soon fill with blood.
6. Insert the tube into the glottis, and inflate; observe the swelling of the whole body, and the inflation of the thin-walled **air-sacs** in the hollow in front of the breastbone.
7. Slit the skin back over the abdomen to the anus, loosen it well back on each side, and cut through the abdominal wall just behind the breastbone; inflate once more, and observe the **abdominal air-sacs.**
8. Break the bone of the upper-arm, the **humerus,** cut through the skin and muscles, and push out through this opening the end of the bone next to the body; note that it is hollow; slip one end of a rubber tube

over the end of the bone, and inflate; what is the result of this experiment? Keeping another tube connected with the windpipe, determine whether air can be sent in through the windpipe and out of the humerus, and *vice versa.*

9. Cut through the body-wall, just behind the margin of the breastbone forward as far as the ribs; raise the breastbone and find the reddish brown **liver.**
10. Lift the liver and disclose, at the left of the body-cavity, a hard mass, the **gizzard.** Slit the abdominal wall in the middle line back to the anus, push aside any fat that may cover the internal organs, and turn the gizzard to the left of the bird to find where the intestine arises from it; trace the intestine from the gizzard backward.
11. The part of the intestine nearest to the gizzard is the **duodenum.**
12. In a long loop formed by the duodenum is a pinkish organ, the **pancreas.**
13. Trace the intestine, tearing away the fat and the thin walls of the abdominal air-sacs, observing that it is held in place by a thin, transparent membrane, the **mesentery.**
14. Near its end the intestine has two short side branches, the **cæca.**
15. Just before the intestine ends, it widens, forming the **cloaca.**
16. Turn the gizzard to the right of the bird; entering it from the front, find a mottled, bulging tube, the **glandular stomach**; pull the crop forward, to show the connection between it and the glandular stomach. To the right of the glandular stomach is the small, red

spleen; seize the gizzard, pull it backward, and cut off the glandular stomach as far forward as possible; remove the gizzard and intestines. Note the relations of the tubes which enter and leave the gizzard; open the gizzard, observing the thick outer muscular coat, from which the gizzard is sometimes called the **muscular stomach.** Note also its tough lining; examine the contents of the gizzard; why does the gizzard have such a thick coat of muscle? do all birds have this kind of gizzard?

17. In front of the liver is the **heart,** in a thin sac, the **pericardium.** Cut through its posterior wall, and turn the heart forward, to see the dark vein, the **inferior vena cava,** running to it from the liver; pull the heart backward, to see the whitish **arteries** running forward from it. The main artery runs forward, and turns to the right before going backward, while in man the corresponding artery turns to the left. Prick a hole in one of the large veins near the heart; insert the point of a blowpipe, and inflate the heart; its red, conical part is composed of the **ventricles;** the dark base is made up of the two **auricles.** Tie a thread around the veins at the anterior and posterior borders of the liver, and cut this organ away.

18. On each side are the pink lungs. Pick away the thin membranes bordering the outer hinder borders of the lungs; look for holes through which the lungs communicate with the abdominal air-sacs; look for the trachea. Remove the lungs, not failing to see how closely they are attached to the back, being indented by the ribs.

19. In the hinder part of the body-cavity are the dark-

colored, irregular **kidneys.** Tear them away, observing how they are composed of several lobes, which fit into the hollows of the **pelvis.** After removing the kidneys, observe the white nerves extending outward from the sides of the spinal column to pass to the thighs.

20. In front of the kidneys are the **reproductive organs;** the two white oval **testes,** in the male; in the female, the **ovary,** often showing many eggs in different stages of development. The kidneys and reproductive organs send tubes to the cloaca; the tube which conveys the eggs from the ovary to the cloaca is the **oviduct.**

21. Remove the heart, cut off the auricles, and look down into the ventricles; cut across the middle of the ventricles, and make a drawing of this cross-section.

22. Cut down into the muscle of the breast, close alongside the ridge (keel) of the breastbone, and around the outer border of the breastbone; thus loosen and raise a great flap of muscle, the **pectoralis major.** Note the nerve and blood-vessels entering its inner surface; separate it from a smaller muscle lying under it, which will be known by the glistening appearance of the muscle-sheath; sever the attachment of the pectoralis major to the breastbone, and all other organs except at the extreme front end; here the muscle narrows into a tough, white cord, or **tendon;** trace this tendon to its attachment to the bone of the arm; now lay the pigeon on its back in one hand, and pull this muscle backward, noting the effect on the wing. In like manner loosen all the posterior attachments of the muscle which was covered by the pec-

toralis major, lying in the angle between the keel of the breastbone and the body of the breastbone; prove its action, this time holding the pigeon right side up. Compare these two muscles in size, and in the amount of work they have to do. The smaller muscle is the **pectoralis minor.** The hinder attachment of each of these muscles is called its **origin**; and the place of attachment of the tendon to the wing-bone is the **insertion.**

23. Observe the fold of skin extending across the angle between the arm and forearm; dissect away the skin, and find a membrane within the skin-fold.
24. Observe the muscles connecting the hinder edge of the breastbone and the pelvis (which were cut through in opening the abdomen); these are the abdominal muscles. How does the bird perform the act of breathing? Compare the bird, snake, frog, and man in their modes of breathing.
25. Bend the leg up close to the body, to the position of perching; what effect does this bending of the leg have on the toes? How does the bird stay securely on the perch when asleep? Dissect the leg to find the mechanism by which the toes are clenched as the leg is bent.
26. Clean away as much as possible of the soft tissues, and keep the skeleton for later study.
27. Dissect out the tongue, and compare it with the tongue of the snake. The voice is produced in the lower part of the windpipe, instead of in the upper part, as in man.

THE BRAIN OF THE PIGEON.

Cut away the top of the skull with a sharp knife, using great care not to injure the soft brain, and make out the following parts: —

1. In front, the large **cerebrum,** consisting of two **hemispheres,** which are separated by a deep groove.
2. Behind the cerebrum is the undivided **cerebellum.**
3. Running backward from the under side of the cerebellum is the **spinal cord**; trace it back into the backbone. Make drawings of the brain, as seen from above and as seen from the side.

THE SKELETON OF THE PIGEON.

Notice the lightness of the whole skeleton. What part of the pigeon's weight is bone? Compare the eye-cavity with that of man. The lower jaw does not join the skull directly, as in man, but is joined to an irregular bone, which, in turn, joins the skull. This is the **quadrate bone.** The hole by which the spinal cord leaves the brain-cavity is the **occipital foramen**; in front of this foramen is a little rounded projection, the **occipital condyle.** Observe how this condyle fits into a cavity in the first vertebra of the neck. Count the vertebræ of the neck, or **cervical vertebræ.** Observe the consolidation of the vertebræ in the back; note the joint in each rib, and the arrangement for bracing the ribs together. Press the breastbone alternately toward the back and away from it, meanwhile watching the joints in the ribs.

The "wishbone" corresponds to the two "collar-bones" of man. Alongside the two branches of the wishbone is a pair of strong bones; what especial need of such bones in this place? In the wing find, in the arm, the **humerus**; in the forearm, the **ulna** and **radius.** The **hand** has only part of the fingers developed; a little bone, representing the thumb, is present (which bore the feathers of the "false wing"). In the thigh is the **femur**; in the leg is the **tibia**; and alongside it, the small **fibula.** The bone above the foot represents the consolidated bones of the human ankle and foot as far as the toes. What evidence is there of such consolidation?

Read "The Anatomy of the Pigeon," in Packard's "Zoölogy" and in Parker's "Zoötomy"; also "Handbook of Vertebrate Dissection. Part II. How to Dissect a Bird," by Martin and Moale.

Trace the pigeon to its family by the aid of Jordan's "Manual of the Vertebrates." Use the same book, or Coues' "Key," for finding the name of any of our wild birds.

THE HEN'S EGG.

So place a hen's egg in a basin of water that it cannot roll, mark the upper side plainly, and boil it hard; keep track of the side that was uppermost.

1. Crack the shell, and pick it away; put a piece of it in strong vinegar, or other acid. Of what is the shell made?

2. Note the thin membrane lining the shell.
3. Does the egg completely fill the shell? Where is the **air-space?** Does the lining membrane, in this region, adhere to the shell or to the "white"? How can a fresh egg be distinguished, without breaking? Does a fresh egg, in water, lie in the same position as when on a table? What is the use of this air-space?
4. How is the yolk situated in the white? how in reference to the position during boiling? Compare a number of eggs, to see if there is any regularity about this.
5. Note the round spot on the yolk, where it comes nearest to the surface. This is the **germ-spot,** in which the chick begins to form.
6. With a sharp knife, split the egg lengthwise. Is the white alike throughout? is the yolk alike throughout? has the yolk a coat? Cut and tear these parts to make out their structure, if they have any definite structure.
7. Boil an egg hard, as before; mark a line lengthwise around the egg, passing through the point that was uppermost while boiling; carefully break away the shell on one side, and with a clean cut remove this half of the white and yolk; place the other half in the position it had while cooking; make a drawing of this section, using different colors to show the shell, shell-membrane, air-space, white, yolk, germ-spot, etc.
8. Prop an egg on end, and boil in this position; is the yolk in a different position in consequence? The white of the egg has interlacing fibres and partitions which keep the mass together; the white cannot be mixed with water till these membranes are cut or broken; hence an egg, to be eaten raw, should be whipped to break these membranes. The white is not

a part of the true egg. In dissecting a bird, the eggs, of various sizes, according to their stages of development, may be found in the ovary. At this time the egg consists of the yolk, with a thin coat; the white is deposited around this later during its descent through the oviduct; the shell is last formed, and is absent in the case of most animals.

In the development of birds all their nourishment, before hatching, must be stored in the egg; hence its large size. In the higher animals the egg is retained in the body of the mother, and gets its nourishment from her blood, which circulates through the embryo.

9. Set a hen on a dozen eggs; mark the date; open and examine an egg each day; if the egg was fertilized, the cells of the germ-spot multiply by division, and soon take definite arrangement; at the end of twenty-four hours the backbone is outlined; during the second day the brain begins to develop, and the heart appears, on the fourth day the legs and wings make their appearance as flattened buds; until the sixth day it would be impossible to say whether the embryo was that of a bird, a reptile, or a mammal; after this, the characters peculiar to birds become evident, the feathers begin to develop, and, later, the particular kind of bird may be recognized.

The development of the rabbit, guinea-pig, or any mammal, including even man, follows nearly the same order as in the chick, the chief differences arising from the fact that the embryo mammal develops in a special portion of the oviduct, the **uterus**, or womb, and that the growing germ is supplied with maternal blood.

The eggs of mammals are very minute. These eggs (if

fertilized) go through the process of division, or **segmentation,** as described for the sea-urchin.

In the embryo of the dog it is twenty-five days before it can be told whether it is to be a mammal or not, and it requires a much longer time to show the distinction between the human embryo and that of the dog. The human embryo and the embryo of one of the higher apes are so closely alike that they are indistinguishable for a still longer time than is necessary to distinguish between the embryos of dog and man.

The study of **development** is called **embryology.**

Egg-laying animals are called **oviparous.** If the young develop within the body of the parent, receiving nourishment from the blood of the parent, the animal is said to be **viviparous**; "or, the young may complete its development while the egg remains in the interior of the body of the parent, but quite free and unconnected with it, as in those vertebrates which are termed **ovo-viviparous.**"

THE RABBIT.

EXTERNAL FEATURES.

1. Note the shape of the body; the relative size of the fore and hind limbs; the length of the ears. Compare the soles of the feet with those of the cat. How many toes has each foot, and how do the claws differ from cat's claws?
2. Make a series of dots showing the tracks made by a running rabbit, indicating by which foot each track is

made, and showing by an arrow the direction in which the rabbit was going.

3. Observe the "**whiskers**" on the upper lip. Examine the **nostrils** and the **cleft** in the upper lip.
4. Note the chisel-shaped front teeth, the **incisors**; observe the space between the incisors and the grinding teeth, or **molars.**
5. Observe the hairiness of the inside of the cheek.
6. Find the third eyelid. How does it compare with that of the pigeon?
7. Save a few of the hairs, and later examine them under the microscope.

INJECTION OF THE RABBIT.

Before beginning dissection it is well to have at least one specimen injected for the sake of comparison. The method of injecting recommended by Parker ("Zoötomy") has given good results. Kill a rabbit with chloroform; as soon as it is dead, open the thorax by cutting through the sternal ribs of both sides, sufficiently far from the middle line not to injure the mammary arteries; cut across the posterior end of the sternum, and turn it forward; slit open the pericardium, and make a large incision, by a single cut with the scissors, in each ventricle; all this should be done very rapidly, if possible before the heart has ceased to beat, as it is desirable to get rid of as much blood as possible; pass a ligature round the aorta close to its exit from the heart, and give it a single loose tie; when the bleeding has ceased, sponge the blood from the heart, and pick away any clots that may have formed in the left ventricle; pass a cannula through the incision in the left

ventricle into the aorta, tighten the ligature, and knot it firmly.

If an injecting-syringe be not at hand, use as a cannula a glass tube so drawn out as to have a notch in it that it may be firmly tied; slip on the outer end of this a short piece of rubber tubing, and insert into this the nozzle of an ordinary syringe.

For the injection mass, fill an ordinary tumbler half full of fine plaster of Paris, colored with a little carmine or yellow ochre; fill the tumbler with water, stir well, and immediately strain the liquid through coarse muslin into a second tumbler. Fill the syringe and inject immediately, as the plaster soon sets. Give a steady, even pressure. On removing the syringe, the rubber tube should be plugged to prevent escape of the liquid.

If the specimen be not injected, the veins can usually be distinguished from the arteries by their greater diameter, thinner walls, and by being of a darker color, retaining the blood, while the arteries are usually empty or nearly so.

ORGANS OF THE ABDOMINAL CAVITY.

1. Slit the skin in the middle line from the breastbone to the pelvis, and strip it well back to the sides. Observe the thin **abdominal muscles,** which form the ventral wall of the abdomen. Carefully slit the abdominal wall in the middle line from the pelvis to the breastbone; from the middle of this slit cut outward on each side and turn back the flaps.
2. The lining of the abdomen is the **peritoneum;** what does it tell the sense of touch?
3. Observe the coiled **intestine,** noting any variations in

size, shape, or markings, but do not now move any part from its natural position.

4. In the front part of the abdomen the dark-colored **liver** may be seen, overlapping the **stomach,** and in the hinder part of the abdomen there may be seen the **bladder,** varying greatly in size and appearance according to its state of distension.
5. Pull the intestine backward, and make out the shape, size, position, and color of the stomach. Observe how the liver and stomach fit together; push the liver forward, and turn the stomach back to find a white tube entering its anterior surface; this is the gullet, or **esophagus.** Just back of the stomach is a small red body, the **spleen.**
6. Find now the connection between the stomach and intestine. Make a drawing of the stomach showing its shape and the connections with the gullet and intestine.
7. Trace the intestine; that part which forms a long loop near the stomach is the **duodenum.** Within this loop is an irregular, fatty-looking mass, the **pancreas.** Find the **pancreatic duct** entering the intestine. This is more easily found in the dog.
8. Observe that the intestine is held by a thin membrane in which are branching blood-vessels; this is the **mesentery**; find its supporting attachment. In tracing its course drag the intestine out of the abdominal cavity, but do not tear the mesentery.
9. The large greenish side-branch of the intestine is the **cæcum.** All the intestine from the stomach to the entrance of the cæcum is the **small intestine**; that part of the intestine posterior to the entrance of the cæcum is the **large intestine.**

10. Turn the stomach and intestines over to the right (of the animal), and observe a pink tube, the main artery, or **aorta,** running along the middle of the dorsal wall of the abdomen. Following this backward, find a branch which subdivides and sends branches to the stomach, liver, and spleen. Farther back a branch is given off to the intestine; follow it as it branches through the mesentery; this is the **anterior mesenteric artery.** Find a branch, the **renal artery,** of the aorta running to the dark-colored, bean-shaped, left **kidney;** finally, the dorsal aorta divides into the two **common iliacs,** extending toward the hind limbs.
11. Turn the stomach and intestines to the left, and observe the two veins running forward from the hind limbs; these are the **external iliac veins,** and by their union they form the **vena cava inferior.**
12. Observe the branches derived from the right and left kidneys, the **renal veins.** Compare the positions of the right and left kidneys.
13. Trace the vena cava inferior to the liver. Observe the vein which gathers the blood from the intestines, the **mesenteric vein;** the mesenteric vein is joined by a vein coming from the spleen, the **splenic vein,** and by the **gastric vein,** from the stomach; these form the **portal vein,** running to the liver; this vein distributes the blood through the liver; the blood is re-collected and empties into the vena cava inferior through the **hepatic veins,** which are almost wholly concealed by the liver.
14. Turn the liver forward, and find on its posterior surface the dark **bile-sac.** The **bile-duct,** by which the bile is conveyed into the intestine, as also the

pancreatic duct, is more easily traced in the dog. By probing with a bristle tipped with sealing-wax these ducts may be traced.

15. Pull back the liver, and examine the thin muscular partition, the **diaphragm,** which extends across the body, separating the chest cavity, or thoracic cavity, from the abdominal cavity. The thin, transparent central part of the diaphragm is its tendon; through this the pink lung, still distended, may be seen. Keeping the eyes fixed on the lung, prick a hole through one side of the diaphragm, and note the collapse of the lung. Is the lung on the other side affected by this operation?

16. Note the passage of the gullet, aorta, and vena cava inferior through the diaphragm.

17. Tie the gullet in two places half an inch apart, and cut through between them. Also double-ligature the hinder part of the large intestine, the **rectum,** and sever it. Remove the stomach and intestines, carefully cutting the mesentery along its whole attachment to the intestine, and uncoil the latter. How many times is the length of the body, including the head, contained in the length of the intestine? Compare the lengths of the small intestine, cœcum, and large intestine. Cut out about an inch of the small intestine in the middle of its course, slit it open lengthwise, wash it thoroughly, and examine, under water, its inner surface with a lens, to see the thread-like projections, or **villi.** In the same way examine a piece of the large intestine. These points may be made out in the intestine of a dog, or from specimens of the calf's intestine obtained from the butcher.

Preserve both specimens in alcohol. Ligature the vena cava inferior just back of the diaphragm and just back of the liver, and cut away all of the liver but that part immediately surrounding the vena cava inferior. To trace the **lacteals** and the **thoracic duct,** feed a kitten or puppy on rich milk, and three hours after place it in a box or under a bell-jar with a sponge soaked with ether or chloroform. When it is completely dead, cut off its head, open the abdomen, spread out the mesentery, and observe in it the white lymphatic vessels, known as lacteals, alongside the veins, converging to form the thoracic duct. Trace this along the aorta. Compare with a kitten that has been fasting eight or ten hours.

THE KIDNEY.

The structure of the rabbit's kidney may be made out by the following directions, but the sheep's kidney, being larger and essentially similar, may be conveniently used. If the sheep kidney be used, its dissection may be made later.

1. Observe the depression in the inner border of the kidney, the **sinus.**
2. From the sinus trace a slender white tube, the **ureter,** back to the bladder. Find also the renal artery and vein branching as they enter the kidney through the sinus.
3. With a sharp knife split the kidney like a bean, beginning at the outer border, stopping the cut when a white membrane is reached near the sinus. With forceps pry about to explore the cavity between this

white membrane and the body of the kidney. Note the branches of this cavity into the kidney. Note also the extension of the white membrane into these cavities. Make out that the blood-vessels extend through these white branches to the outer parts of the kidney. Count these branches.

4. In the center of the white membrane find the opening of the ureter, through which the urine is conveyed to the bladder. Pass a probe through this opening into the ureter.
5. Note the difference in color of the outer and inner parts of the kidney. At the line of change of color find where the blood-vessels first branch into the real kidney substance. Examine carefully the cut surface of the kidney to see its markings.
6. Make a drawing of one-half of the kidney as seen from the inside, showing all the above-named points.
7. Cut across the middle of the kidney at right angles to its length, and make a drawing of this cross-section. The projection of the kidney substance into the cavity opposite the ureter is the **urinary pyramid,** and from its apex, through many fine holes, issues the urine which the kidney has secreted from the blood.

THE BRAIN AND SPINAL CORD.

1. Slit the skin along the middle of the back from the nose to the tail, and strip it back well to the sides. Dissect away the muscles from the back of the head and the fore part of the neck; between the skull and the first vertebra, or **atlas,** is a space covered by a thin membrane, through which the white **spinal cord**

may be seen. Insert the point of one blade of a pair of strong scissors, or bone-forceps, at one side of the spinal cord, and cut this side of the arch of the atlas; repeat with the other side, and continue thus through several vertebræ, raising and turning them back. Observe the coat which covers the spinal cord and lines this canal in the backbone, the **neural canal.** Note the groove along the center of the cord.

2. Turn now to the head and insert one blade of the bone-forceps at one side of the entrance of the spinal cord into the skull. Cautiously cut and break away the whole roof of the skull. This work may be done with a strong knife, but the bone-forceps are best. The tough membrane covering the brain and adhering to the skull is the **dura mater.**
3. The fore part of the brain is the **cerebrum**; observe the groove separating it into the right and left **hemispheres.** Observe the shape of the cerebrum, and the general character of its surface.
4. The prolongations of the cerebral hemispheres between the eyes are the **olfactory lobes.**
5. Back of the cerebrum is the **cerebellum.** The partial bony partition between them was probably noticed in removing the roof of the skull.
6. The part of the spinal cord within the skull is called the **medulla oblongata.** Make a drawing of the brain. If there be enough time, postpone 7 and 8 till the completion of 9–17. Carefully cut away the dura mater over the brain.
7. Cut through the olfactory lobes at the front of the cerebral hemispheres, and carefully pry up the front end of the cerebrum. Running forward and outward

from the base of the brain will be seen the **optic nerves.** Cut these close to the bone beneath.

8. Back of the optic nerves are the small **third** and **fourth pairs** of nerves, then the larger **fifth,** the small **sixth,** and close together the **seventh,** the **facial,** and **eighth,** the **auditory,** and farther back four more pairs. Cut these all where they leave the brain-cavity.

   If 9–17 are not to be done the same day, the spinal cord may now be cut an inch back of the brain, and the brain be put into alcohol for later study.

9. Lay the rabbit on a narrow box, and let the head hang over one end. Cut away as much as possible of the muscle along the backbone. With the bone-forceps unroof the whole length of the spinal cord in the manner before described.

10. Note carefully the variations in the diameter of the spinal cord in its course.

11. Observe the **spinal nerves,** passing off in pairs through the spaces between the arches of the vertebræ. Count the pairs of nerves, and compare them in size in the different regions of the backbone.

12. Carefully cut away the bone and other tissue around some of the nerves in the region of the shoulder, and make out that each spinal nerve has two roots, an upper, in the natural position of the animal, and a lower. These get their names from human anatomy, the former being the **posterior root,** and the latter the **anterior root.** Trace them to their union in the one spinal nerve.

13. On the posterior root, just before it joins the anterior, find a swelling, the **ganglion** of the posterior root.

14. In the region of the shoulder carefully trace several nerves on each side as they unite to form the **brachial plexus,** branches from which supply the fore limb.
15. In the region of the hips, in like manner trace several large nerves to their union in the **lumbo-sacral plexus,** the main nerve from which may be followed down the back of the thigh, the **sciatic nerve.**
16. Compare the color of the brain with that of the spinal cord.
17. Make a drawing of the brain and spinal cord. Remove the brain and cord with the plexuses, and put the whole into alcohol.

THE BRAIN OF THE RABBIT.

(Alcoholic Specimen.)

The brain of a cat or dog is better, being larger. Take a brain well hardened in alcohol, or a strong solution of bichromate of potash, and review the parts as named above.

1. Press down the cerebellum to see the deep groove between it and the cerebrum. The thin membrane covering the brain and dipping into the grooves is the **pia mater.**
2. Press down the medulla oblongata, and tear away the pia mater where it passes from the cerebellum to the medulla oblongata. Note, between the medulla and the cerebellum, a space covered by a thin membrane. Cut through this membrane; the cavity is the **fourth ventricle** of the brain. Observe the two ridges bounding the sides of the fourth ventricle. At their point of divergence, observe the opening of the **central canal** of the spinal cord.

3. Gently separate the cerebral hemispheres, and note the transverse band of white fibres connecting them.
4. Examine the under surface of the brain and find the roots of the cranial nerves.

The **olfactory lobes** (probably cut or broken off) extend forward from the fore part of the cerebral hemispheres.

Note that the **optic nerves** join each other before reaching the brain. Only the first and second pairs of cranial nerves directly enter the cerebrum.

Further back is the **third pair** of nerves.

The **fourth pair** extend up on each side into the groove between the cerebrum and cerebellum.

Back of these is the larger **fifth pair.** This pair supplies part of the face and sends branches to the teeth. It is the nerve affected in neuralgia of the face.

Back of, and inside of, the fifth pair is the smaller **sixth pair.** The third, fourth, and sixth pairs control the movements of the eyeballs.

The **seventh pair** are larger and are farther back and outward. These are **facial nerves,** and control the muscles of the face and the facial expression.

Close to the seventh is the **eighth** or **auditory nerve.**

The **ninth, tenth,** and **eleventh** arise close together further back, and well up on the side of the medulla oblongata.

The ninth supplies the back of tongue and the pharynx, and is called the **glosso-pharyngeal nerve.**

The tenth pair pass down out of the brain-cavity, give off branches to the pharynx and larynx, and are

distributed to the heart, lungs, and stomach; hence the name **pneumogastric nerves.**

The last pair of cranial nerves, the **twelfth,** arise nearer the middle line of the medulla oblongata. This pair supplies the muscles of the tongue and are called the **hypoglossal nerves.**

Draw the brain as seen from below, showing all these nerves.

5. Separate the cerebral hemispheres, and with a sharp knife split the brain lengthwise in the middle line. Make a drawing of the inner face of one-half. Note the branching **arbor vitæ,** of the cerebellum. Trace the cavities of the brain.
6. Trace the blood-vessels of the brain. For this the brain of an injected rabbit or dog should be used.
7. Cut and examine cross-sections of the spinal cord after it has been hardened in alcohol. Compare the colors of the inside of the brain and spinal cord.

ORGANS OF THE THORACIC CAVITY.

1. Remove the skin from the throat and chest. With scissors cut through the rib-cartilages along one side of the breastbone, slightly separate the edges of the cut, and note the position of the heart.
2. Cut along the other side of the breastbone and note the thin partition, the **mediastinum,** attached to its inner surface. Cut the hinder end of the breastbone loose and raise it; sever its attachment within and turn it forward. Observe the collapsed lungs on either side. Examine the anterior surface of the diaphragm.

3. Note that the heart is, normally, in the plane of the mediastinum, and that this membrane entirely separates the two halves of the chest.
4. Take the heart between the thumb and finger to feel how easily it slips about in its sac, the **pericardium.**
5. Cut away the mediastinum and the pericardium, and note the appendages, **auricles,** at the large end, or **base,** of the heart.
6. Cut away the breastbone entirely, press the ribs out to the sides, and dissect away a thin layer of muscles covering the windpipe, so that the blood-vessels which run forward from the heart into the neck may be traced. Carefully pick away a fatty-looking body, the **thymus gland,** in front of the heart and trace the following arteries.
7. The main artery, the **aorta,** is a whitish, thick-walled tube. Springing forward from the centre of the base of the heart, it soon arches over to the left (of the animal) and runs along the middle of the dorsal wall of the chest-cavity, piercing the diaphragm, as noted in studying the abdominal cavity.
8. At the **arch** the aorta gives off two branches; the first of these soon subdivides, giving off a branch to the right fore limb, the **right subclavian artery,** a branch running along each side of the windpipe, the right and left **common carotid arteries** (called common because each as it nears the head divides into the **internal carotid** and the **external carotid**). The second branch from the arch is the **left subclavian artery.**
9. Just outside of the common carotids on each side are the white, thread-like **pneumogastric nerves.**

10. Observe on each side of the neck the dark **jugular vein** running back toward the heart; note that each of these is formed by two main branches, the **external** and **internal jugular veins**, which unite just back of the head.
11. Just before each jugular vein enters the chest-cavity it receives a branch from the corresponding fore limb; these are the **subclavian veins.** The union of the jugular and subclavian veins on each side forms the **vena cava superior.**
12. Trace the right vena cava superior straight back to the right auricle. Turn the heart forward and follow the course of the left vena cava superior in reaching the same auricle.
13. The large vena cava inferior, coming forward through the diaphragm to the right auricle, is easily seen.

    The heart and lungs may now be removed, and the pulmonary artery and veins traced, and the structure and action of the heart made out by the following directions; but the heart and lungs of the pig, calf, or sheep will show the same features much better on account of their greater size.

THE HEAD OF THE RABBIT.

Remove the skin from the head.

1. Below and back of the ear is an irregular pink mass, the **parotid salivary gland.** The duct which conveys its secretion runs forward and opens on the inside of the cheek. It is hard to trace in the rabbit. Find it in the dog, slit into it with fine scissors, and push a bristle forward through it to find its opening in the mouth.

2. Note the branches of the **facial nerve** running upward over the cheek. Dissect away the parotid gland, and find where the facial nerve emerges from the skull.
3. In the angle between the two branches of the lower jaw observe two roundish bodies, the **submaxillary salivary glands.** In the dog trace their ducts as in the case of the parotid.
4. Observe the muscle which covers the outside of the back part of each lower jaw. This is the **masseter muscle.** Place the fingers on the angle of your own jaw and note the action of the masseter muscle in shutting the teeth firmly together. In the rabbit note the attachment of the masseter to the under edge of the cheekbone. Trim the muscle entirely away.
5. After removing the submaxillary glands, a muscle will be found on each side having its origin on the inside of each half-jaw near their junction. These are the **digastric muscles;** they depress the lower jaw. Cut away all the muscles and other connections and remove the whole of the lower jaw.
6. Carefully examine the tongue.
7. Thoroughly clean the lower jaw and examine the teeth. How is the lower jaw hinged to the skull, and what motion does this hinge allow? How does the rabbit move its lower jaw? What is the relation between this jaw-motion and the direction of the ridges on the grinding teeth, or **molars?**
8. Observe the opening on the inner surface of each half-jaw where the nerve entered to supply the teeth.
9. Look at the side of the back part of the mouth for an opening leading toward the ear, the **Eustachian tube.**
10. Trace the **nasal passages.**

THE LEGS OF THE RABBIT.

Most of the following structures may be made out from a shinbone of a sheep, readily obtained from the butcher.

1. After removing the skin from the legs, observe the **muscles,** covered by a thin glistening membrane, the **muscle-sheath.** Study the shape of the muscles.
2. Note the white **tendons** which terminate the muscles.

   Loosen the tendons from surrounding tissues and separate the muscles from each other along their sides without cutting them. Pull the different muscles to determine the motion each produces.

   A muscle which straightens a limb is an **extensor.**

   A muscle which bends a limb is a **flexor.**
3. The large tendon running along the back side of the shinbone is the **tendo Achillis**; it corresponds to what part of our bodies? to what part of the horse?
4. By further dissection find how the different movements of the toes are effected.
5. Cut into the knee-joint. Observe the liquid, the **synovia,** which oils the joint. Rub a drop of it between the thumb and finger.
6. Observe the glistening bands which hold the ends of the bones together. These are the **ligaments.** Carefully study their arrangement and uses.
7. Note the thin layer of **cartilage** over the ends of the bones. Feel of it. Cut it. What are its properties, and what its uses?
8. With the forceps strip off a little of the muscle-sheath from one of the muscles and note the color of the latter. Cut one of the muscles across in its middle and examine the cross-section. Each fibre has its

own thin sheath, and the small bundles of fibres have separate sheaths, which make the white markings seen in chipped dried beef.

9. Tear off a few fine fibres of the muscle, mount on a slide in water, or glycerine, cover with a cover-slip, and examine first with a low and then with a high power. The fine cross-markings of the fibres give to this kind of muscle the name of **striped,** or **striated, muscle.**
10. Thoroughly clean one of the long bones and make a drawing of it. Saw it in two lengthwise and make a drawing of the surface thus exposed. Put a bone into weak acid, and after a day or two compare it with another, that has been burned.

For a more complete guide to the study of the rabbit, consult Parker's "Zoötomy"; and "Practical Physiology," Foster and Langley.

THE HEART AND LUNGS

OF PIG, SHEEP, OR CALF.

Get the heart and lungs entire as first removed from the body and "cut long," the "pluck," as the butchers call it.

1. Hold the mass up by the windpipe, with the heart toward you; you now look at the front of the heart as it hangs between the lungs.
2. Observe the windpipe, or **trachea**, with its stiff rings of gristle, or **cartilage.**
3. Back of the windpipe is a soft red tube, the **gullet;** find where it is cut off below, or cut across it, and note its whitish lining, the **mucous coat.** The thick red

coat is the **muscular coat**; try to make out an inner layer of circularly arranged fibres and an outer longitudinal layer.

4. Separate the gullet and windpipe and compare the front and back surfaces of the latter; cut across the windpipe and make out the shape of the rings of cartilage.
5. Observe the smooth rounded posterior surfaces of the lungs which were fitted against the ribs on each side of the spinal column.
6. Lay the lungs on the table, with their posterior surfaces down, and with the point of the heart extending away from you. The surface of the heart now uppermost is its **anterior** surface, the side to your right is its **right side**, and its **left side** is to your left. The point of the heart is its **apex**, and the large end is its **base.**
7. If the sac which surrounds the heart, the **pericardium,** be not already cut away, note how easily the heart moves about in it, and then slit it along its anterior surface. Observe the **pericardial fluid.**
8. Carefully compare the right and left sides of the heart. Observe a groove running obliquely along the anterior surface of the heart in which run blood-vessels, often covered by fat. The part to the right of this groove is the **right ventricle**; the part to its left is the **left ventricle.** Press the two sides and note the difference in firmness.
9. At the base of the heart, on each side, find an ear-like appendage, with notched margins; these are the **right** and **left auricles.**
10. Seize the apex of the heart and tip it up toward you. Compare the front and back surfaces of the heart. Compare the thickness of the heart from right to left

and from front to back. Hold the heart between the two hands, with its apex up, and again compare the firmness of the two ventricles.

11. Turn the heart to the left and examine the right auricle; find a large, red-walled tube entering it from the front; this is the **superior vena cava,** which brings the blood from the head, neck, and fore limbs to the right auricle. Trace this vein forward to the point where it was severed (or if this is not readily found, prick a hole in it); insert the point of the blowpipe, pinching the vein closely about it, and inflate the vein. Meanwhile watch closely the posterior part of the auricle; there should be discovered another tube entering the auricle from behind, the **vena cava inferior,** which passes forward through the diaphragm; find where it was severed, and inflate the right auricle through it, holding the vena cava superior if necessary. By this inflation the outlines of the right auricle and ventricle should be determined.

12. Turn the heart to the right and observe a large, light-colored tube arising from the base of the right ventricle between the two auricles; this is the **pulmonary artery**; again turn the heart to the left and raise the right auricle; find a second large artery arising from the center of the base of the heart; this is the main artery, or **aorta.** Carefully separate the aorta and pulmonary artery above the base of the heart.

13. Trace the aorta as it arches over and runs down between the two lungs behind, alongside the gullet; find where it was cut off. With knife and scissors cautiously clear away the whole **arch** of the aorta from the surrounding tissues.

14. From the arch of the aorta arise the branch or

branches which supply the head and fore limbs. Compare the branches, as here found, with those of the rabbit's aorta, and of the human aorta as shown by the cuts in any text-book of human anatomy and physiology.

15. Now trace the **pulmonary artery** and its two branches as they subdivide to the right and left lungs.
16. Follow the branches, the **bronchi,** of the windpipe to the lungs. Follow one bronchus as it is distributed through the lung. Observe the structure of the lung. Cut a lung in two, and on the cut surface find the flabby ends of the blood-vessels and the stiff ends of the branches of the bronchi. With a probe trace the latter back to the trachea.
17. Try to distinguish the **pulmonary veins**; those from the right lung run close along the right auricle on their way to the left auricle.
18. Cut the pulmonary arteries and veins near the lungs, trim away the pericardium close to the heart, and keep the heart in a cool place for further study.

THE STRUCTURE AND ACTION OF THE HEART.

1. Make three full-size drawings of the heart, front view, back view, and side view, naming the parts and blood-vessels as given above.
2. With scissors slit down the vena cava superior, and continue the cut across the back of the right auricle, and for a short distance along the back of the vena cava inferior. Explore the cavity of the right auricle. Opposite the entrance of the vena cava inferior observe, in the red inner wall of the auricle, a rounded depression, the **fossa ovalis,** across the bottom of

which is stretched a paler membrane; by slight pressure with the handle of the forceps, prove that this membrane is thin and yielding. Below the fossa ovalis is the opening of the **azygos vein.** With a syringe inject water into it and find whence it comes.

The projection between the entrance of this vein and the fossa ovalis is the **Eustachian valve.** With scissors slit open the azygos vein and find, entering it, veins from the walls of the heart. Trace these veins.

3. Cut away the whole of the right auricle; hold the heart in the left hand, with the left ventricle resting against the palm; pour water suddenly from a considerable height into the right ventricle, watching closely to see the valves float up and separate the auricle from the ventricle. Pour in water again, and as soon as the valves rise, press with the fingers on the outside of the right ventricle; note the effect of this pressure. Where does the water escape?
4. Empty the heart and examine the valves which have been seen; they will now be found lying close against the walls of the ventricle. Note the white cords attached to the lower edges of these valves.
5. Push a finger past these valves to the very bottom of the ventricle; from the outside cut through the wall of the ventricle at this point, and cut cautiously upward along the border of the cavity of the right ventricle. Raise the outer wall of the ventricle and more thoroughly study the valves; slip a blunt instrument between the flaps of the valves and the walls to which they adhere, and raise them so they can be better seen. How many flaps are there, and how are

they arranged? How are they held in place? How are they acted upon, and how do they act?

6. Find the connection between the right ventricle and the pulmonary artery. Cut away the wall of the right ventricle so that the beginning of the pulmonary artery may be seen from below. Hold the heart up by the pulmonary artery and force a stream of water through the pulmonary artery toward the heart. Look from beneath to see the filling and bulging out of the valves at the beginning of the artery. Note the number, shape, and arrangement of these valves. What is the effect of the stream of water on them, and what is their effect on the stream of water? Slit the artery and examine the valves from above. These are the **semilunar valves.**

7. Examine the left auricle to find where the pulmonary veins enter it; cut the auricle away from the ventricle and examine it from the inside to see the openings of the pulmonary veins. Pour water into this ventricle as with the right. Compare the valves of this and the right side of the heart.

   Cut off the aorta near the heart; watch the opening of the aorta when water is poured into the ventricle, to see the action of the valves. In the pockets of the valves of the aorta look for the openings of the arteries which supply the walls of the heart with blood.

8. Cut open the left ventricle and compare its walls with those of the right ventricle. Why are they different? Note the partition between the ventricles; is there any direct communication between the right and left halves of the heart?

THE VALVES IN THE VEINS.

Dissect back the skin from the throat of the rabbit, cat, or dog, till the jugular veins are well exposed. Let the head of the animal hang over the edge of the table; note that as the blood presses back toward the head it causes marked bulging at certain points; with the handle of the forceps slightly stroke the vein toward the head, watching the bulgings. Dissect out the jugular vein from the head to the shoulder; insert the nozzle of a syringe, first into one end and then into the other, and show the effect of forcing currents in each direction. Cut the vein open along one side, pin inside out to a piece of a shingle and examine the thin pocket-like valves. Test the elasticity of the vein. Note the smoothness of its inner coat. Remove a piece of an artery and experiment in the same way with it.

DEMONSTRATION OF THE ACTION OF THE HEART.

Get the heart and lungs entire. Dissect out the aorta as before. Clear the pulmonary artery and cut off both branches close to the lungs. Carefully trim away the pericardium and clean the venæ cavæ inferior and superior. Turn the heart back and find one of the larger pulmonary veins; cut a hole in it near the lung and slip a glass tube into it toward the heart; this tube should have a groove, made by drawing it out in the flame; tie the tube firmly in, and ligature the other pulmonary veins without stopping to trace them. Tie any and all connections with the heart now remaining and cut beyond the ligatures. Get a retort-stand and two large glass funnels.

Place the funnels in the rings. Lay the heart, now wholly severed from the lungs, on its front surface. Connect one funnel, by rubber and glass tubing, with the left auricle by the tube already in the pulmonary vein; connect the other funnel with the right auricle through the vena cava superior; ligature the vena cava inferior. Lay the heart in a basin and pour water into the funnels; hold the heart with the two hands and compress it, repeatedly adding water. In this way the clotted blood usually present in the right ventricle may be washed out. If this remain, it may interfere with later experiment. Connect the aorta with the funnel which leads to the right auricle, by means of a glass tube which bends over the edge of the funnel, thus holding itself in place by the hook, and emptying into this funnel any liquid which escapes from the tube.

In like manner have a bent glass tube, from the pulmonary artery, hooked over the edge of the funnel leading to the left auricle.

Pour water into one of the funnels and compress the heart to imitate its natural contraction; observe where the liquid next appears; add more water and follow it around to its starting-point. A little ink may be poured into one of the funnels and traced around, as the heart is worked, to its starting-point.

That there is no direct connection between the two halves of the heart may be shown by letting the liquid from each artery empty into the auricle of the same side of the heart. Different colored liquids may be used in the two funnels.

THE MUSCLES OF THE EYEBALL.

With bone-forceps, or a strong knife, cut away the bone at the outer angle of the eye-socket of the rabbit (almost any mammal will serve for this, though the bone is so thick in the calf or sheep that it will be difficult work without the aid of a good pair of bone-forceps).

1. With scissors trim away the white membrane around the front of the white of the eye; this was continuous with the lining of the eyelid, and is the **conjunctiva.**
2. Find a muscle running along the roof of the eye-socket, which passes through a loop of tendon, near the edge of the orbit, and turns outward to its attachment to the top of the eyeball. This is the **superior oblique muscle.**
3. Beneath the eye find a muscle, having its origin in the inner front part of the socket, and passing outward to be inserted in the lower surface of the eyeball; this is the **inferior oblique muscle.**
4. Four straight muscles, the **inferior, superior, internal,** and **external recti,** are attached to the top, bottom, and sides of the eyeball; find the origin of these, with that of the superior oblique, at the posterior extremity of the eye-socket.
5. Dissect away the fat and other tissue around these muscles, and find a cone-shaped muscle attached to the back of the eye. Within this find the cylindrical **optic nerve.**

EXTERNAL PARTS OF THE EYE.

The eye of the rabbit may be used, but that of the ox is better.

1. Observe the clear front part of the eye, the **cornea.** Note its shape. Its wider end was at the inner angle of the eyelids.
2. Around the cornea find a whitish membrane, the **conjunctiva,** which a short distance back from the cornea separates from the eyeball to turn forward and line the eyelid.
3. The severed muscles of the eyeball, a mass of fat which forms a cushion for the eye, and other tissue, should be trimmed away leaving the **optic nerve,** which enters the eye below and outside of the centre of its posterior surface; the place of entrance of the optic nerve, together with the shape and natural position of the cornea, will serve to distinguish the right and left eyes.
4. Place the eye in its natural position, and make drawings of it as seen from the front, from behind, being still careful to have it right side up, and from one side, naming the parts, and stating whether it be the right or the left eye.

DISSECTION OF THE EYE.

1. Lay the eye on a plate with the cornea uppermost. Hold the eye firmly with the thumb and fingers of one hand; with the thumb and forefinger of the other hand hold one blade of the scissors half an inch from its tip; with a steady motion push the blade horizontally through the cornea near its edge.

2. The liquid in the cavity back of the cornea is the **aqueous humor.**
3. Cut around the margin of the cornea and remove it.
4. The dark membrane now exposed is the **iris.** Pinch the eye slightly at the sides to make the iris show more distinctly. The hole in its centre is the **pupil.** With the forceps raise the edge of the iris around the margin of the pupil to see that it is here unattached to the structures underneath. Observe the color and markings of the iris.
5. From one end of the pupil cut outward to the outer margin of the iris, then cut around its outer margin and remove it. Observe the color and markings of its posterior surface.
6. The body now laid bare is the **crystalline lens.** Touch it.
7. With a sharp knife make a quick light gash across the surface of the lens to cut through the thin coat which envelops it, the **lens capsule.** Enlarge the opening thus made and carefully pry out the lens with the handle of the forceps, noting closely, in so doing, the difference between the front and back surfaces. Lay the lens on a piece of newspaper and look through it at the letters. Make a drawing of the lens as seen from the front, and as seen from one side, naming the front and back surfaces.
8. With the forceps seize the lens capsule where it was cut and pull it gently but firmly to one side; this action will probably tear the mass within the eye loose from the outer coats; repeat the pull in all directions. With the scissors now cut outward about one-fourth of an inch from the edge of the hole made

in the front of the eye; then cut clear around the eye and remove a strip of this width, thus enlarging the opening before made. On the inside of the strip removed there may be found radiating black ridges, the **ciliary processes.** Note part of these ciliary processes around the margin of the lens capsule.

9. Carefully pick away with the forceps and snip away with the scissors everything on the surface of the clear mass beneath.
10. The substance filling the remainder of the eye-cavity is the **vitreous humor.**
11. Through the vitreous humor the entrance of the optic nerve may be seen with the blood-vessels radiating from it.
12. The tough outer coat of the eye is the **sclerotic coat.**
13. Inside the sclerotic is the dark **choroid coat.**
14. The inner, nearly transparent coat is the **retina.**
15. Drag out the vitreous humor and note the soft whitish retina; observe that it is a continuation of the optic nerve. Tear away the retina, noting its consistency. Note the color and luster of the inner surface of the choroid coat.

    The reflection of light from this surface of the choroid coat causes the color seen in the eyes of some animals. Turn the remaining coats inside out and tear the choroid coat from the sclerotic. Observe the blood-vessels passing from one to the other.

THE LARYNX OF THE CALF.

1. The front of the larynx is readily distinguished by the projection of cartilage known as the **Adam's apple.**

2. Along the back of the larynx runs a thick muscular tube, the **gullet,** with a white lining membrane.
3. Trim away the muscles and other tissues from the front and sides of the larynx. The large cartilage forming the greater part of the front of the larynx is the **thyroid cartilage.**
4. Observe the band of muscle attached to either side of the thyroid cartilage and passing horizontally back around the esophagus.

   Cut away this muscle as completely as possible and entirely remove the gullet. Note that the whitish or yellowish **mucous membrane** which lines the gullet is continuous with the lining of the larynx. Study now more fully the shape of the thyroid cartilage.
5. Back of the upper part of the thyroid cartilage, covering the upper end of the larynx, is the arched **epiglottis.** Feel of it to learn its consistency. Press it upward and forward, then downward and backward; observe that it now covers the entrance to the larynx; note the position it takes when released.
6. Just back of the upper angle of the thyroid cartilage find a muscle connected with the base of the epiglottis; pull this muscle to determine what effect its contraction produces on the epiglottis.
7. Under the thyroid cartilage in front observe a narrow ring of cartilage not much wider than one of the rings of the trachea. Move this up and down to prove that it is distinct from the thyroid. This is the **cricoid cartilage.**
8. Observe the sheet of muscle passing from the cricoid to the thyroid. Again move the cricoid toward and from the thyroid; what does this muscle do? Cut

away this muscle from one side and see that the cricoid cartilage widens as it passes backward. How are the cricoid and thyroid hinged together?

9. Projecting upward and backward from the top of the larynx are two curved yellowish cartilages, the **arytenoid cartilages.** Move them about to see that they are movable and that they rest on the upper edge of the back part of the cricoid cartilage.
10. With one hand move the arytenoid cartilages backward and forward, meanwhile watching the inside of the larynx from its lower opening. The projecting ridges, which meet just back of the Adam's apple, are the **vocal cords.** What effect is produced on the vocal cords by the movements of the arytenoid cartilages?
11. Observe the connection of the thyroid cartilage with the cricoid by means of a downward projection of the former. Cut away all of this half of the thyroid cartilage. Notice the slender **hyoid bone** loosely connected with the upper bone of the thyroid.
12. Examine now the muscles which move the arytenoid cartilages.
    a. On each side of the posterior surface of the cricoid is a muscle passing upward to be attached to the corresponding arytenoid; this is the **posterior crico-arytenoid muscle.** Dissect it loose from the cricoid, at its origin below. By pulling, determine its action on the arytenoid, and through the arytenoid on the vocal cord.

    b. Arising from the upper edge of the side of the cricoid cartilage, and passing upward and backward to the arytenoid, is the **lateral crico-aryte-**

noid muscle; cut away at its origin close to the cricoid and demonstrate its action on the arytenoid cartilage and vocal cord.

c. A broad muscle arising along the whole length of the angle of the cricoid, whose fibers converge to the arytenoid cartilage. This is the **thyro-arytenoid muscle**; cut it across near its origin, dissect it loose, and by pulling it toward its origin prove its action.

d. On the posterior surfaces of the arytenoids is the small **arytenoid muscle.**

13. Cut between the arytenoid cartilages and remove one of them. Examine the joint between the arytenoid and cricoid. Note the synovia lubricating the joint.

    Trim away the muscle from the arytenoid cartilage and study the shape more fully. Fit it again to its place and recall the motions given by each muscle.

14. Now examine the arytenoid cartilage and the vocal cord of the opposite side; move the arytenoid back and forth, watching the vocal cord.

15. Remove the epiglottis and cut into it to see its structure.

16. Dissect away the parts of the other side from the inside, reviewing the above points.

THE STARFISH.

For this work there is needed: —

1. A set of dried specimens, one for each student; such a set may be used with successive classes and will last for years if carefully handled and kept in a dry place.

2. Alcoholic specimens for dissection.
3. It is desirable to have a set of prepared slides, showing cross-sections of a decalcified ray of a young starfish, and a ground-down section of a calcareous plate, etc.
4. An injected starfish and a number of injected rays.

The above and other desired material for work on marine animals may be obtained of Mr. B. H. Van Vleck, Boston Society of Natural History, Boston, Mass.

DRIED SPECIMEN.

1. Observe, first, the shape of the body as a whole. The central portion is the **disk** and its radiating extensions are the arms, or **rays.** Note that the rays are bilaterally symmetrical.
2. The mouth is at the center of a thin membrane in the middle of the **oral surface**; the opposite surface is called **aboral.**
3. Cut into one of the rays. Observe that the body cavity is bounded by a leathery wall in which are imbedded hard plates. Compare a piece of a ray of an alcoholic specimen with the dried one.
4. Test the flexibility of the integument of the alcoholic specimen. By picking with forceps, prove that there is soft matter, both on the outside and on the inside of the hard plates. To show the real nature of the plates and their relation to the integument, proceed as follows: —

    a. Handle a starfish which has been decalcified, *i.e.* has had its calcareous matter removed by very weak (two per cent) nitric acid, chromic or other

acid. Observe that the body wall is still present but lacks the hard parts.

b. Examine a microscopic section of a decalcified ray of a young starfish; in such section it should be more clearly seen that the calcareous plates are wholly within the integument.

c. To show still further the relation between the plates and the integument, prepare a thin section of a calcareous plate, as follows: select some pieces of a starfish (left from previous dissection). Boil a few of the larger plates in caustic potash in order to remove all the organic matter; wash, and when thoroughly dry, smooth down one side on a fine file; polish on a perfectly clean oil-stone; cement this surface of the plate to a glass slide by means of a drop of Canada balsam which has been boiled on the slide, until on becoming cold it is with difficulty indented by the thumb-nail. Proceed then to plane off, by means of a file, and when quite thin, scrape carefully with a sharp knife, finally smoothing it on an oil-stone. The specimen should be examined from time to time under the microscope, in order to ascertain when the proper degree of thinness has been reached. Dissolve the balsam by means of turpentine, or better, if properly managed, melt the balsam over a lamp and carefully push the section into a watch-crystal containing turpentine; when thoroughly freed from balsam, carefully brush it with a camel's-hair brush and mount in Canada balsam in the ordinary manner.

5. Observe the arrangement of the plates and spines in

different regions of the body wall. Along the middle of the oral surface of each ray may be seen the shrivelled remains of the tube feet, or **ambulacra.** The region in which they lie is the **ambulacral area.** The plates along this tract are the **ambulacral plates.** One row of plates on each side of these ambulacral plates are known as the **inter-ambulacral plates.** Examine these closely for comparison with the sea-urchin.

6. The wart-like elevation on the aboral surface is the **madreporic body.** Note that it is situated opposite one of the **inter-radial angles.** Examine it with a lens.
7. Make drawings of the oral and aboral surfaces of the starfish.

ALCOHOLIC SPECIMEN.

1. Briefly review the points noticed in examining the dried specimen. Bend the rays; their flexibility is now much less than in life.
2. Compare the spines of different areas as to their shape, size, and degree of mobility.
3. Between the spines are soft, tapering projections, the **aboral tentacles.**
4. Observe a circle of projections surrounding the spines; delicately pinch them with the forceps to determine their consistence; remove some of these bodies to strong alcohol; mount temporarily in turpentine on a slide, cover, and examine with a low power. There should be distinguished a short stalk bearing a pair of pinchers; these bodies are the **pedicellariæ.** In the live starfish these pinchers may be seen continually snapping; they are supposed to serve in removing foreign matter from the body.

5. The soft cylindrical projections along the median tract of the oral surface of each ray, are the **ambulacra** or **tube feet.** Remove one of them and examine it with care. Note the arrangement of the series.
6. Press apart the tube feet and find running along the median line of the ambulacral groove, a yellowish or whitish ridge, the **nerve** of the ray. Trace it to the soft membrane bordering the mouth, the **peristome,** and find the **nerve ring** around the mouth.
7. Trace the nerves also to their outer ends and find a reddish or yellowish elevation, the **eye-spot,** borne at the base of a median terminal **tentacle,** resembling a tube foot.
8. The eye-spot is borne on a distinct, but minute, plate. Compare young and old specimens to see that whatever the size, this single ocular plate with its eye-spot is always at the end of the ray. Count the ambulacral plates in a short and in a long ray. Where do the new plates develop?

DISSECTION OF THE STARFISH.

1. The ray opposite the madreporic body is the **anterior ray.** Cut through its aboral wall near the outer end, and from this point cut along the upper part of each side of the ray, an inch or two toward the disk; raise the flap thus freed, and, avoiding internal organs, continue the cut on each side to the disk.
2. Attached to the aboral wall find a pair of elongated, branched bodies, the **hepatic cæca.** Note how each cæcum is held in place by the thin **mesentery.**
3. Along the middle line of the aboral wall, inside, is a yellowish streak, the **extensor muscle** of the ray; with forceps prove its general structure.

4. Along each side of the ridge in the floor of the ray, observe rows of thin-walled sacs, sometimes distended, but more often collapsed in alcoholic specimens. These are the **ampullæ,** or **ambulacral vesicles.** Watch the ampullæ while pressing on the tube feet, and *vice versa.* If a specimen injected with coloring matter be at hand it should now be examined.
5. Near the base of the ray find, on each side, an elongated body resembling a bunch of grapes, and of a lighter color than the cæca; these are the **reproductive bodies** and are very much alike in appearance in the two sexes, and only distinguishable by color or by microscopic examination in the living specimens. Find the point of attachment of one of them. The openings in the inter-radial angle are not very evident.
6. Cut along the sides of the two rays lying on the right and left of the anterior ray, connect the cuts at the inter-radial angles, and turn back the cover of the three rays and disk. Within the disk is the large, thin-walled stomach. Examine this organ carefully. Pass a blunt probe through the mouth and explore its interior.
7. Observe the large lobes of the stomach extending a short distance into the rays; lift one of these lobes and trace the thin **retractor muscles** of the stomach to the sides of the ridge in the ray.

   In the live starfish the stomach is often found protruded and surrounding a mussel or an oyster; after digesting and absorbing its soft parts the stomach is retracted.
8. Turning to the cæca of the anterior ray, trace them toward the stomach; find the union of their tubes

and the entrance of their common duct into the stomach. Observe the place where this tube enters the stomach, in reference to the corresponding lobe of the latter.

Carefully cut the mesentery along the aboral wall and wholly free the cæca of this ray from all attachment above. Note that the mesentery is double.

9. Hold the starfish inverted and pour water through the mouth into the stomach to show its shape.
10. In the other two rays which have been opened, cut across the common ducts of the cæca close to the stomach, and leave them attached to the aboral walls.
11. Find the extremely short intestine connecting the stomach with the upper wall of the disk, near the junction of the extensor muscles of the rays. Find, also, some small branched appendages of the intestine. The anal opening is minute.
12. Sever the intestine close to the aboral wall, cut across the disk close to the madreporic body, and remove entirely the roof of the disk and the three rays.

    Make a drawing of the organs now exposed, showing the cæca in one ray, the reproductive bodies in another, and the ampullæ in the third.
13. Thoroughly examine the stomach, and remove it after cutting across the short esophagus.
14. The S-shaped **stone canal** may now be seen passing downward from beneath the madreporic body.
15. Traced to its lower end, the stone canal may be found to enter a membranous hollow ring, whose outer border rests against the inner surface of the hard parts surrounding the mouth; this tube is the **circum-oral water-ring.** Connected with its inner surface, find

several pairs of pouches, which in the contracted state are mere button-like projections. How many of these are there, and are they all in pairs?

Observe also the pouches, like ampullæ, connected with the upper part of the hard ring around the mouth. Press on the water-ring at the level of the peristome, and watch the effect of this action on these last-named pouches or vesicles. Is there any connection between them and the water-ring?

16. Enclosing the stone canal is a thin membrane, the **pericardium.** Carefully tear it away. Alongside the stone canal is a soft tube, the **heart.** In the live starfish it may be seen to pulsate.

17. Cut across the middle of a ray in two places, about an inch apart, and make a careful study of the part included between the cuts. Remove the hepatic cæca, observing again how they are suspended by the mesenteries. Cut through the aboral wall in the middle line and spread open the ring. Observe the depressions in its inner surface; in the bottoms of these depressions find small holes. What is the relation between these holes and the nearest structures seen on the outside?

18. Slowly peel away the thin membrane which lines the interior of the ray, noting especially the connection between this membrane and the depressions above noticed. Also watch closely the aboral tentacles while tearing away this lining membrane.

19. Turn now to the outside of the ray and gently scrape the surface. A thin layer here may also be easily removed. Thoroughly clean a small area, noting that the aboral tentacles come away with this layer.

There will now remain a tough white layer in which are imbedded the calcareous plates which constitute the skeleton. Bend this membrane to see the relations of the calcareous plates to the membrane and to each other.

20. By picking with the forceps prove that the membrane is continuous over both the inner and outer surfaces of the plates, as well as between them. This is an important point, as the calcareous plates are developed in and by the membrane.

Part of the membrane, if not all, has the power of contracting, by means of which motion is effected. Note the perforations in the membrane in its thinner portions between the plates where the aboral tentacles passed out.

21. Reviewing what was noticed in the examination of the inner and outer membranes, it will be evident that the aboral tentacles are tubular extensions of the body formed by the protrusion of the inner membrane through the middle membrane, these tubes being covered by the outer membrane.

22. Turn now to the tube feet and their ampullæ and make out their relations to each other and to the adjacent parts of the skeleton. The calcareous plates which form the sides of the ambulacral groove are the ambulacral plates.

23. Pick away a few of the ampullæ, and then the corresponding tube feet, comparing the arrangement of the two. In this way clean the ambulacral plates and examine them carefully.

24. Alternately press the ambulacral plates of the two sides together and separate them to see the range of

motion allowed by the joint. Observe the muscles connecting the ambulacral plates of the opposite sides, just inside of the nerve.

25. In the angle formed by the ambulacral plates, find the cut-off end of the **water-tube** of the ray. Insert in the end of this, the point of a drawn-out glass tube, and inflate. When the ampullæ are distended, press on them with the finger and note the effect on the tube feet; with a lens examine the distended ampullæ. In fresh specimens the ampullæ may be injected with a colored liquid or with gelatine to be kept as permanent preparations. In such preparations and in a microscopic section of a properly prepared ray, it may be seen that the water-tube of the ray sends off side branches to the tube feet, and also that the cavities of the tube feet and ampullæ are continuous. By the contraction of the ampullæ the tube feet are extended, and by the muscles in their walls they are moved from side to side and applied to the surfaces on which the starfish rests. The end is fixed by means of the sucker-like disk at the tip of the foot to some foreign object; then by the contraction of the tube feet, the starfish pulls its body along.

The water finds its way through the madreporic body into the stone canal, thence to the water-ring around the mouth, and from this to the radial canals. The water thus taken in probably serves for respiration as well as for locomotion.

26. Make a drawing of a cross section of a ray, showing as many as possible of the above noted points of structure. A slide with a series of very small starfishes shows well how the rays are formed as outgrowths of the disk.

For the anatomy and development of the starfish and sea-urchin, see Brooks' "Handbook of Invertebrate Zoölogy," Hyatt's "Common Corals, Hydroids and Echinoderms" (No. V. of "Guides for Science Teaching"), "Seaside Studies in Natural History," by E. C. and A. Agassiz, Romanes' "Jellyfish, Starfish, and Sea-Urchins" (Vol. XLIX. in the International Scientific Series).

THE SEA-URCHIN.

The requisites for this work are, cleaned skeletons, or tests, alcoholic specimens, microscopic sections, etc., as in the case of the starfish.

THE CLEANED TEST.

1. Observe the radial distribution of the parts around an axis, at one pole of which is a large opening.

   At the opposite pole is a circular area composed of several small plates, near the center of which is the anal opening.
2. Note that the test is composed of distinct pieces or **plates.** Put one of the plates into a little dilute acid and note what occurs.
3. To make out the real nature of the skeleton, proceed thus: —

   a. Handle an entire decalcified specimen, *i.e.*, one from which the calcareous matter has been removed by chromic or other acid. Observe that the body walls and spines are still present.

b. Examine a microscopic section of the decalcified body wall to see that there was soft living matter, both on the outside and on the inside of the calcareous plates.

c. Grind down and mount a thin section of a plate, as in the case of the starfish, and see that not only is the plate wholly enclosed in the body wall, but that it forms a network whose meshes were penetrated by the soft living substance of that body-wall. It should now be clear that the plates were formed by the deposition of calcareous matter within the living tissues of the body wall. The joints, or sutures, between the plates are formed by the absence of the deposit of calcareous matter.

4. Returning to the entire test, study the arrangement of the plates, their variations in shape, size, etc.

   Into how many similar areas may the surface of the test be divided? To make out these points, and the shapes of the plates, pull apart a piece of a dried test that was left over from previous dissection.

5. At the aboral pole, observe a small distinctly marked-off area, including numerous small plates. This is the **anal area,** and the plates are the **anal plates.** Unlike the other plates, these, in the living sea-urchin, are movable. They surround the **anus.**

6. Surrounding the anal area are the five large **genital plates,** each having a **genital opening** near its outer angle.

7. With a lens examine the largest of the genital plates; its perforated portion serves as a **madreporic body.**

8. Radiating from the apex of each genital plate, is the

zigzag **inter-radial suture.** How many kinds of plates are found within the area included by two adjacent inter-radial sutures? The perforated plates are the **ambulacral plates,** and the unperforated, the **inter-ambulacral plates.** Compare these two sets of plates with the corresponding parts of a starfish.

9. The ambulacral plates form the **ambulacral areas.** Trace each of the ambulacral areas to its aboral end, and find at its apex a small plate wedged in between two adjacent genital plates. These smaller ones are the **ocular plates.** Note the small opening from which projects an unpaired tentacle, the end of the radial water-tube.
10. Carefully compare the hard parts of the starfish and sea-urchin. Wherein are they alike, and wherein do they differ? What changes in growth would be necessary to convert one of these forms into the other? What part of a starfish is homologous with the anal area of a sea-urchin?
11. Make careful drawings of the oral surface, of the aboral surface, and of the side of the test.

ALCOHOLIC SPECIMEN.

For the sake of review and comparison, it is well to have the cleaned test before one in this study.

1. Observe the soft membrane, the **peristome,** on the **oral surface** and the **teeth** projecting from the **mouth.**
2. At the aboral pole look for the anus and genital plates.
3. Examine one of the largest spines; move it about to

see its range of motion. Remove it and make out how it is articulated to the test. The fleshy tube ensheathing the base is muscular tissue, by the contraction of which the spine is moved. Clean the spine and make a drawing of it.

4. Note any variations in size and shape of the spines in various regions.
5. Study carefully the arrangement of the spines, using the cleaned test for comparison.
6. Between the spines in certain areas find soft tubular projections, the **tube feet** or ambulacra. In life they may be extended a considerable distance beyond the spines, being used for locomotion as in the starfish; carefully examine the tips of the **tube feet** to find what is therein contained.
7. Find also among the spines and on the peristome, slender flexible stalks, bearing three-pronged pinchers. In life these pinchers keep opening and shutting.
8. Pick away the spines and other projections preparatory to dissection.

DISSECTION OF THE SEA-URCHIN.

After removing the spines, cut, or better, saw with the blade of a metal saw, through the equator of the test; place under water and carefully raise the aboral portion at one side.

1. Press on the tips of the teeth to show their connection with the complicated apparatus known as the **lantern;** now open the test till the two halves are side by side and complete the dissection under water.
2. Arising from the middle of the inner surface of the lantern find the brown **esophagus.** Trace this as it

passes in festoons about the body walls, widening to become the stomach. Trace the intestine to the anus, describing carefully its course.

3. Pick away the alimentary canal from the oral half of the test. Note the five double rows of ampullæ; between each of these double rows runs the radial water-tube, and between the water-tube and the test, is the radial nerve.
4. In the aboral half, note the reproductive bodies in the loops of the intestine. Trace their ducts to the genital pores.
5. After cleaning away the intestine and reproductive bodies, trace the ampullæ as they converge to the ocular plate. Compare the inside and outside of the test to see if the ampullæ are really opposite the ambulacral pores noticed in the dry test.
6. Study the lantern, make out how it is supported, and how its various parts are moved, and how they are used.

Place in water the pieces of tests left after dissection and macerate till the spines are readily detached. Then clean and keep them for the next class. They will be useful for pulling to pieces to make out the structure of the test. The sea-urchin and the star-fish may be taken as convenient types of the branch **Echinodermata.** To this group also belong the Brittle Stars, Holothurians, and Crinoids.

THE DEVELOPMENT OF THE SEA-URCHIN.

The reproductive bodies are very much alike in the two sexes, distinguishable only by color or by microscopic examination.

In the dark-colored sea-urchin (*Arbacia punctulata*) the ovaries are red, from the color of the contained eggs, while the testes are white. Through the genital openings already observed, there passes out into the water from the female a multitude of red spherical eggs. From the male there passes into the water a white liquid, which on examination with a high power of the microscope is seen to be composed of myriads of little bodies, the **spermatozoa,** like slender tadpoles, and swimming by the active vibration of their tails.

If these two elements meet in the water the egg may be fertilized; otherwise, the egg does not develop, but soon dies. This process of the fertilization and the changes that the egg undergoes in consequence, have been studied in the following manner: —

Live sea-urchins were opened, the ovaries and testes removed, and torn open to let their contents escape. The ova and spermatozoa were mixed in a watch crystal of sea water and watched under the microscope; the actively swimming spermatozoa surround the ova; just how the fertilization is accomplished is not fully known; it is believed that a spermatozoon enters the ovum. After this the egg mass contracts, leaving a clear space around it inside the outer coat, or cell wall; soon the egg mass within divides into two equal parts, each of these halves again divides into two, the four then become eight, sixteen, thirty-two, and so on till the number can no longer be counted and the egg looks like a spherical mulberry. This berry-like mass now becomes hollow, next one side is pushed in like a rubber ball with one side punched in; on the outside are little hair-like projections of the cells, called **cilia,** which by their vibrations propel the body

through the water. A set of needle-like rods develop within, which soon make a skeleton shaped somewhat like a common chair. This skeleton has a covering of soft tissue, and the projections which correspond to the legs of the chair are covered with strong cilia for locomotion. The digestive tube has at first but one opening, that made by the doubling-in of the outer wall, as above mentioned, and the cavity of this depression forms the digestive cavity. The mouth is formed later by a new opening made through the outer wall into the first cavity and the original opening becomes the anus. So far the young sea-urchin is very unlike the adult; but after a time this larva begins to transform into the real sea-urchin, and soon the little sea-urchins, about the size of pins' heads, are found crawling up the sides of the glass vessels in which they are kept.

The first of the changes here described should be carefully remembered, as this division, or **segmentation,** of the egg is common to all but the very lowest animals, though the manner of division may greatly vary.

THE FRESH-WATER HYDRA.

The fresh-water hydra has a cylindrical **body,** varying in diameter from the size of a fine needle to that of a common pin, and from one-fourth to one-half an inch in length. It is found in fresh-water ponds and streams, usually attached by one end to submerged stems, leaves, etc., frequently on the under surface of a leaf. Surrounding the free end of the hydra is a circle of thread-like appendages, the **tentacles,** which often are longer than the body itself.

Two species of hydras are found; one green, the other brown or flesh-colored. Put the leaves and stems to which the hydras are attached into shallow dishes, such as fruit-dishes, and keep them in a light but shaded place; watch their behavior when thus kept undisturbed. Cut off a bit of leaf bearing a hydra, and transfer it to a deep watch crystal half full of water. Without the aid of any lens watch the hydra for several minutes. When it is expanded, gently touch it with the tip of a pencil or other blunt object.

Examine a hydra with a hand lens; are all parts colored alike? Place the watch crystal on the stage of a microscope and examine with a one-inch objective. The following points of structure should now be made out: —

1. That the body is a **hollow tube** closed at one end and open at the other. This opening, within the circle of the tentacles, is the **mouth**.
2. That the tentacles are also hollow tubes, closed at their outer ends, but at the inner communicating freely with the body cavity.
3. That the body wall consists of two layers, which are continuous with the corresponding layers of the tentacles. How do these layers differ from each other?

   The body is, then, a double-walled sac, and the tentacles are simply extensions of this sac. Watch the movements of the different parts of the body. Can hydras move from place to place? If so, how is this accomplished? Look in the body cavity for foreign matter which has been taken in through the mouth as food. Look also for minute particles obtained by the digestion of such food matter. These particles may often be seen in motion, caused by contractions

of the body walls, or by the action of cilia lining the body cavity. Look for knob-like extensions of the side of the body. **Buds** are formed as outgrowths of the body walls with a cavity continuous with the body cavity. Place in a dish by itself with some aquatic plants, a hydra bearing buds, and watch from day to day the development of the bud into the form of the parent. Observe the free circulation of food material from the parent to the bud. Watch the formation of tentacles. Look also for a thinning away of the free end of the bud.

What is the greatest number of buds found on any one specimen? Are buds borne on buds? By means of a pipette transfer a hydra in a large drop of water to a slide. Cut two strips of thick paper a quarter of an inch long and one-sixteenth of an inch wide and lay one on each side of the drop of water. Carefully place the coverslip on the water, with its edges resting on the papers so as not to crush the specimen.

Examine now with a quarter or one-fifth inch objective. Observe the cells of which the body walls are composed. Note the knotty appearance of the tentacles. In these projections of the tentacles and in the walls of the body are certain distinct oval cells, the **thread cells.** Place a drop of acetic acid on the slide at one edge of the coverslip, and touch the opposite edge of the coverslip with a piece of blotting paper, meanwhile watching the specimen closely. Examine carefully to see the thread-like prolongations of the thread cells which have been discharged as a result of the irritating acid. Small animals coming in contact with the tentacles are

paralyzed by means of these threads which are suddenly shot out; the tentacles then carry the victim to the mouth and it is swallowed.

Note the simplicity of the structure of hydra — the absence of any distinct nervous system, and all special organs of circulation and respiration.

Hydras have been cut into slices, lengthwise and crosswise, and each part not only continued to live but grew into a perfect hydra. Hydras have also been turned inside out and in a short time digested food as usual, what had been the outer layer of the body now becoming the lining of a stomach. The tentacles when cut off do not live.

Besides multiplying by budding, hydra also produces ova and spermatozoa in projections of the body walls. Both kinds of sexual elements are produced in the same individual. Such an animal is called a **hermaphrodite.**

There is a large group of animals, almost without exception marine, constructed on essentially the same plan as hydra, though often much more complicated. Hence the hydra is the **type** of the group known as the **Hydroids.** Many of them live in colonies, as if the young hydras, instead of dropping off from the parent and becoming distinct individuals, remained attached with a free communication between them all. At least two distinct forms of individuals are commonly found: —

a. A hydra-like form, devoted to obtaining and preparing nourishment for the colony, hence called the **nutritive zooid.**

b. Modified forms, producing the generative elements, the **generative zooids.**

c. Besides these two are often found forms modified for protection, etc.

If a stained and mounted specimen of a campanularian or other hydroid be at hand, it will be found very useful in showing these points.

The different kinds of individuals, though often greatly modified, still show the essential plan of the hydra. Some hydroids have a tube of hard material developed by the outer layer, and at the base of the colony some kinds secrete a layer of this material incrusting the object on which the colony is borne. Some forms spread by runners like strawberries. One form is common on the shells inhabited by hermit crabs. Others are attached to seaweed, while still others are dredged up from great depths of the ocean.

Among certain forms of hydroids the generative zooid becomes peculiarly modified in form, and ultimately becoming detached, is known as a **free generative zooid, jelly-fish,** or **medusa.** These jelly-fishes, or medusæ are usually either bell-shaped or umbrella-shaped, the part answering to the top being called the **bell** or **disk.** Corresponding to a short handle is the **manubrium.** This has at its free end an opening, the **mouth.** The handle is hollow, and communicates with tubes radiating through the disk, answering to the umbrella rays. These tubes are connected by a circular tube, extending around the margin of the disk. Along this margin are tentacles and organs for receiving impressions of light or sound. Most jelly-fishes swim by contracting the umbrella-like disk.

Along the radiating tubes, or in the manubrium, are borne the generative elements; the eggs develop

into hydra-like forms, which, on becoming attached, give rise by a process of budding, to a hydroid colony, some members of which assume a medusa form, thus completing the cycle. This mode of development has been called, though inappropriately, an alternation of generations. All jelly-fishes do not, however, develop in this way. Jelly-fishes are richly supplied with lasso-cells, and the larger ones sting severely, being dangerous to bathers.

Read the description of Cyanea and other jelly-fishes in "Seaside Studies."

THE SEA-ANEMONE.

In its general form the sea-anemone resembles a hydra, having a cylindrical hollow body attached by one end to some foreign object, and at the free end a mouth surrounded by tentacles. In its internal structure, however, the sea-anemone presents some new features. The mouth, instead of opening directly into the body cavity, as in the hydra, opens into a stomach which hangs like a bag suspended in this cavity; the stomach has no bottom, but at its lower end communicates freely with the body cavity.

The body wall and stomach may be represented by a glove-finger with its tip cut off and the open end turned back part way into the larger part of the finger.

The cavity of the body is divided into a series of radial compartments by fleshy vertical partitions, the **mesenteries,** which extend inward from the body wall, some reaching the stomach and being attached to it, others not ex-

tending as far inward as the stomach. Each tentacle communicates with one of these radial compartments, and is to be regarded as a mere extension of part of the body cavity.

Alcoholic specimens should be sliced transversely and longitudinally. In a transverse section of the lower part of the body there will be seen the body wall with a series of partitions extending inward and ending in a free edge. The section across the upper part of the body shows an outer circle, the body wall, an inner circle, the stomach wall, and, connecting the two, the radially arranged partitions, or mesenteries. Like the hydroids, the sea-anemone is well provided with lasso cells.

Food is taken into the mouth, digested in the stomach, then passed, mixed with sea water, into the body cavity, through which it is made to circulate by the contractions of the body walls. The indigestible portions of the food are expelled from the stomach through the mouth.

The tentacles are often brilliant and variegated in color; and when the sea-anemone is expanded, it well proves the fitness of its name. For a very interesting description of these beautiful animals read Mrs. Agassiz's little book, "A First Lesson in Natural History" (No. IV. in "Guides for Science Teaching").

CORAL POLYPS.

The coral polyps are similar to the sea-anemone in their general structure. They usually grow in colonies with their bases connected by a continuous layer of living matter, from which the polyps grow by budding.

Through this common base the cavities of the polyps communicate, more or less directly, so that food obtained by one may nourish the whole colony. The coral polyps also differ from the sea-anemone in forming a deposit of hard matter. Representatives of the two kinds of coral should now be examined.

STONY CORALS.

(*Corals Proper.*)

In a piece of stony coral, or compound skeleton of a colony of coral polyps (*Galaxea* is a good form to study), make out the following points: —

1. The nature of the material itself; test by putting a very small piece into weak acid, or by touching the specimen with a drop of acid.
2. The **cup,** or **theca,** formed by an individual polyp, often traceable as a long tube. Observe, —
   a. The outer wall of the cup.
   b. The partitions, or **septa,** extending inward from the wall of the cup.
3. Between the cups, the porous limy secretion, which was secreted by the common body substance, or **cœnosarc,** connecting the individual polyps.

   Imagine the sea-anemone depositing limy matter in the base of its body wall, forming a cup; fleshy radial ridges rising from the floor and wall of the cup between the mesenteries, and a similar deposit in these ridges; thus it will be seen how the cup is formed by

the individual polyp. By the continued growth of the polyp, and the continuation of the limy deposit, the cup becomes an elongated tube. By budding are formed the branches of these tubes, increasing in size and in the number of partitions as they grow.

4. Between the cups, a porous secretion of the same material as that in the cups. This is deposited in the common fleshy base, filling up, in some forms, the spaces between the cups; and when one polyp dies, its cup is covered over and buried out of sight by this secretion of the common base.
5. Make a drawing of a mass of stony coral, showing the general arrangement of the cups, their mode of branching, and the common secretion between them.
6. Draw a cup as seen from its free end. Make also a drawing of a cross-section of the same cup toward the smaller end.

In the stony corals the mesenteries are always in pairs, and the fleshy ridges, in which are secreted the septa, arise between them.

The tentacles are generally in multiples of six, and are not fringed. It is of this kind of coral that the reefs are formed.

SEA-FEATHER, OR SEA-FAN.

In a sea-feather, *e.g.*, *Muricea*, note: —

1. An outer bark-like layer; with the thumb-nail scrape off a little of this layer and pulverize it between the thumb and finger; mix this powder with water and examine under a microscope. A better way to see

the spicules is, to thoroughly clean them by boiling some of the outer layer in caustic potash. In this layer are holes from which the polyps protruded. In this form, then, the secretion is wholly in the living matter between the polyps, the bark-like layer being composed of the dried flesh in which the spicules lie imbedded.

Strip off a piece of the bark-like layer and note the grooves on its inner surface. By examining the end of this piece it may be seen that these grooves are caused by a series of tubes running lengthwise near the inner surface of this layer. Find the openings of the tubes where they were broken; these tubes connect the polyps of the colony.

2. The central axis of horn-like substance. Test its flexibility and strength. Observe the grooves on its surface, and the relation between them and the tubes above noted. This horny axis is excreted by the walls of these tubes, and is not penetrated by living matter like the outer layer. In the precious red coral the central axis is formed in the same way, but is calcareous instead of horny, and the outer bark-like layer has been removed.

3. Note the mode of branching in a sea-fan, comparing the margin with the central portion to see how the meshes are formed. Remove some of the outer layer, and compare with the sea-feather. In this group (including sea-feathers, sea-fans, the precious red coral, etc.) each polyp has eight fringed tentacles; also eight mesenteries, which are never in pairs. An alcoholic specimen, with the polyps expanded, should, if possible, be examined.

The hydroids, jelly-fishes, sea-anemones, and coral polyps, with many other interesting forms, belong to the branch **Cœlenterata.** The cœlenterates are many-celled, radially symmetrical animals, and never possess a digestive tube wholly cut off from the body cavity.

SPONGES.

Each pupil should have a small specimen of a commercial sponge, showing large holes at the top, but not with large holes running straight through.

The teacher will need several specimens of larger sponges; one of the simple calcareous sponges, in alcohol; a piece of a commercial sponge in alcohol, showing the sponge-flesh still in place; a silicious sponge; and slides showing sponge spicules.

The pupil should make out the following points from his specimen: —

1. Its elasticity; test first the specimen dry, and again after wetting it. Compare the elasticity of different kinds of sponges.
2. The fibrous structure; with forceps tear off a bit of the sponge and examine with a lens. Then examine under the microscope.
3. The sponge was attached by its basal surface to rock. Find where it has been trimmed away with shears; perhaps if this has not been thoroughly done, some bits of rock may be found clinging to the base.
4. Examine now the different channels by which the sponge is perforated.

a. Large crater-like tubes, opening at the top of the sponge. Looking into these, it may be seen that they give off branches. If you can see right through the sponge by looking into these openings, you may know that too much of the base has been cut away, and your specimen is not a good one. With a razor or sharp knife, cut the sponge in two down one of these large tubes, and examine from the inside.

b. Trace the branches of the large tubes by gently pushing into them a probe (a wire with a little knob on one end). These lead, usually, to holes seen on the outside.

c. Grooves on the surface of the sponge, some shallow, others already becoming enclosed by the union of the tufts of fibres outside of them; in this way is formed another set of tubes (*d*).

d. Tubes running parallel to the surface of the sponge, whose cut-off ends may be seen near the margins of the split sponge. Hold the half sponge up to the light to see the radiating fibres and the concentric series of holes indicating the mode of growth of the sponge.

e. Minute branches of the above tubes penetrating the sponge in all directions.

It must be borne in mind that the sponges we buy are only the skeletons of sponges. In the living sponge the skeleton is entirely imbedded in soft living matter, and the skeleton cannot be seen on the exterior; in fact, its fibres are not very evident in a section of a fresh sponge. The outside of the sponges whose skeletons we buy, when alive resembles, in color

and general appearance, the back of a kid glove, varying from dark reddish-brown to almost black. The consistency of the living sponge is about the same as that of beef liver. If one of these live sponges be watched, a current of water is found to come out of the larger holes at the top, and currents pass in through the numerous smaller holes on the exterior.

If the sponge be handled, many of the smaller holes close and entirely disappear.

In order to understand a little more clearly the structure of the common sponge, and to see how the currents of water are maintained, an examination of a simple sponge will be useful. Our simplest sponges have no elastic skeleton composed of horny fibres like those of the commercial sponge, but have little needle-shaped and three-pronged spicules of limy matter.

One form common on the northern Atlantic coast is a simple or branched white tube, an inch or so in height and sometimes as thick as a pigeon's quill. These are in clusters, attached by one end and open at the other. Imbedded in the wall of each tube are the spicules above mentioned, projecting both on the outside and on the inside. The inside of the tube is lined with cells bearing cilia which, by their vibration, drive the contained water out of the mouth of the tube; to replace which, water enters through many holes which pierce the wall of the tube. In sponges a little more complicated, the cilia, instead of lining the main tube, are limited to small pouches, or lateral branches of the main tube, extending into the body wall and communicating with the exterior through small pores. In others the cilia are found only in certain enlarged portions

of these radiating tubes. This represents the condition in the commercial sponges; certain cavities are lined with cilia and are connected on the one hand with the smaller tubes entering the whole surface of the sponge, and on the other with the large tubes opening at the top. These cilia cause the currents above mentioned. Thus the sponge gets both food and oxygen.

Sponges (including, besides those already mentioned, silicious sponges, whose spicules are flinty) constitute the branch **Porifera.**

For a very interesting account of the gathering and preparation of sponges for the market, read "Commercial and Other Sponges" by Hyatt (No. III. in "Guides for Science Teaching").

REVIEW OF ALL THE ANIMALS STUDIED.

1. How many different plans of structure have been shown by the animals thus far examined?
2. How many different ways of eating, and how do the digestive organs differ?
3. What different arrangements for the circulation of the blood?
4. Compare the various methods of breathing.
5. In what ways do animals effect motion and locomotion?
6. Describe the different sorts of organs of feeling, seeing, hearing, smelling, and tasting.
7. Describe the methods of producing sounds.
8. What different kinds of coats do animals wear?
9. What weapons of attack and defence do they carry?
10. What different kinds of skeletons?

How many kinds of animals are native to your neighborhood?

The animals of a given region constitute its *fauna*. Thus, the faunæ of North and South America are unlike; and North America may be divided into regions having more or less distinct faunæ.

What characters are common to all the animals you have studied?

What is an animal?

BRANCHES OF THE ANIMAL KINGDOM.

(*Packard.*)

8. Vertebrata: Mammals, Birds, Reptiles, Batrachians, Fishes, etc.
7. Arthropoda: Crustaceans and Insects, Spiders, Myriapods, etc.
6. Mollusca: Bivalves, Snails, Cuttle-fishes, etc.
5. Vermes: Worms.
4. Echinodermata: Crinoids, Starfishes, Sea-urchins, etc.

3. Cœlenterata: Hydroids, Jelly-fishes, Polyps, etc.
2. Porifera: Sponges.
1. Protozoa: Amœba, Paramœcium, Vorticella, etc.

BOOKS OF REFERENCE FOR THE ZOÖLOGICAL LABORATORY.

Of the following books, Nos. 1 to 9 are almost indispensable. For general reference, at least, one of the first three should be at hand, and every one of 4 to 9 gives great aid in practical work.

1. TEXT-BOOK OF ZOÖLOGY. Claus & Sedgwick. Macmillan & Co. 2 vols. $8.00.
2. ZOÖLOGY. Packard. Henry Holt & Co. $3.00.
3. TEXT-BOOK OF ZOÖLOGY. Nicholson. D. Appleton & Co. $1.50.
4. HANDBOOK OF INVERTEBRATE ZOÖLOGY. Brooks. Cassino. $3.00.
5. PRACTICAL BIOLOGY. Huxley & Martin. Macmillan & Co. $1.50.
6. PRACTICAL PHYSIOLOGY. Foster & Langley. Macmillan & Co. $2.00.
7. GUIDES FOR SCIENCE TEACHING. Hyatt and others. D. C. Heath & Co. 10–40 cts. each.
8. FIRST BOOK OF ZOÖLOGY. Morse. D. Appleton & Co. $1.00.
9. ZOÖTOMY. Parker. Macmillan & Co. $2.25.
10. THE CRAYFISH. Huxley. D. Appleton & Co. $1.75.
11. ANATOMY OF VERTEBRATED AND INVERTEBRATED ANIMALS. Huxley. 2 vols. D. Appleton & Co. $2.50 each.
12. GUIDE TO THE STUDY OF INSECTS. Packard. Henry Holt & Co. $5.00.
13. INSECTS INJURIOUS TO VEGETATION. Harris. Cassino. $6.00.

14. Insects Injurious to Fruits. Saunders. J. B. Lippincott & Co. $3.00.

15. Vegetable Mould and Earthworms. Darwin. D. Appleton & Co. $1.50.

16. The Naturalist's Assistant. Kingsley. Cassino. $1.50.

17. Comparative Zoölogy. Orton. Harpers. $1.80.

18. Seaside Studies in Natural History. Mrs. E. C. and Alexander Agassiz. Houghton, Mifflin, & Co. $3.00.

19. Spiders, their Structure and Habits. Emerton. Cassino. $1.50.

20. Life on the Seashore. Emerton. Cassino. $1.50.

21. Manual of the Vertebrates. Jordan. Jansen, McClurg & Co. $2.50.

22. Synopsis of the Fishes of North America. Jordan & Gilbert.

23. Key to the Birds of North America. Coues. $10.00.

24. The Butterflies of the Eastern United States. French. J. B. Lippincott & Co. $2.00.

25. The Cat. Mivart. Scribners. $3.00.

26. The American Naturalist. Cope & Packard. Monthly. $4.00 a year.

TYPES OF MARINE ANIMALS FOR LABORATORY USE.

Protozoa.

Foraminiferal sand. Bahamas.

Sponges.

Commercial sponge. Small hand specimens for class use. Florida Keys 25
Same. Section mounted on slide 1
Same. Alcoholic specimen showing fleshy matter. Small piece in vial 1
Sea cap sponge. Florida Keys 1
Calcareous sponge in vials. New England 6
Microscopical prep. Showing spicules in place 1
Silicious sponge. New England 1
Spicules of same. Mounted 1
Chalinula. Pieces.

Cœlenterates.

HYDROIDS.

Tubularia. In vials. New England 12
Tubularia. Exhibition cluster.
Clava on seaweed; clusters in vials. New England . . . 12
Hydractinia colonies on shells 4–6
Campanularian. In vials 12
Campanularian colony. Stained and mounted. Slide . . 1
Campanularian jelly-fish. Stained and mounted. New England 1
Sertularia on seaweed. Dry. New England.

ACTINOIDS.

Sea-anemone. New England 6
Sea-anemone. Section on slide 1
Stony coral (Galaxea). Pacific. Small hand specimens . . 20
Alcyonarian coral (Muricea). Dry. Florida Keys. Ex. spec. 1
Same. Branches for class use 20
Same. Branch in alcohol showing polyps expanded . . . 1
Same. Slide with spicules of skeleton 1

ACTINOIDS.

Sea-fan. Bahamas	1
Same. Horny axis	1
Same. Spicules mounted	1

Echinoderms.

Starfish for dissection. New England	25
Same. Dry	25
Same. Prepared, showing skeleton	1
Same. Decalcified	1
Same. Injected rays showing water system	5
Section of plate showing microscopic structure. Mounted	1
Young starfish showing the budding out of rays. Stained and mounted	1
Large *W. I. Starfish* (Oreaster)	1
Brittle stars (Ophiurans). Dry	3
Sea-urchins. Alc. For dissection. New England	25
Same. Tests. Dry	25
Same. Alc. specimen decalcified	1
Same. Section of plate showing microscopic structure. Slide	1
Large *W. I. Sea-urchin* (Hipponoë). Test	1
Clypeastroid (Sand-dollar), with spines	1
Clypeastroid (Sand-dollar), without spines	2
Clypeastroid (Echinanthus). W. I.	1
Holothurian. Common sea-cucumber (Pentacta). New England	1
Synapta. Microscopical preparation showing plates in body wall	1

Worms.

Nereis in test-tube. Alc.	1
Polyzoan (Bugula). Dry.	
Brachiopod (Terebratulina). Alc.	2

Mollusks.

Clam killed with siphons extended	1
Mussel. Alc. or shell	1
Carnivorous sea-snail (Lunatia)	1
Carnivorous sea-snail (Purpura)	2
Limpet. Alc. New England	2
Squid. New England	2

Arthropods.

CRUSTACEA. New England.

Lobster. Small specimen. Dry	1
Shrimp. Alc.	2
Crab. Dry or alc.	2
Goose barnacle. Alc.	3
Acorn barnacle. Dry.	
King crab (Limulus). Small specimen. Alc.	2
Same. Medium size. Dry	1
Same. Moults. Small specimens	3

INSECTS.

White ants (Termites). In vial. Bahamas.

Ascidians.

Ascidia. New England	1
Boltenia. New England	1

Vertebrates.

Young shark (Acanthias). 6 inches. New England	3
Small *skate.* New England	1
Flounder. New England	1

The above collection, carefully prepared and designed especially for class work, may be obtained from B. H. VAN VLECK, Boston Society of Natural History, Boston, Mass.

Price (including packing), $25.00.

SCIENCE.

"Thinking again the thoughts of God."

Organic Chemistry:

An Introduction to the Study of the Compounds of Carbon. By IRA REMSEN, Professor of Chemistry, Johns Hopkins University, Baltimore. Adapted to the needs of all students of Chemistry, whether they intend to follow the pure science, or to deal with it in its application to the arts, medicine, etc. $5\frac{1}{4} \times 7\frac{1}{2}$ inches. x + 364 pages. Cloth. Price by mail, $1.30; Introduction price, $1.20.

THIS book is strictly an *introduction* to the study of the compounds of Carbon, or Organic Chemistry, and is intended to meet the wants of students in our scientific schools, medical schools, schools of technology, and colleges. It is difficult to see how, without some such general introductory study, the technical chemist and the student of medicine can comprehend what is usually put before them under the heads of "Applied Organic Chemistry" and "Medical Chemistry." The book is perhaps rather more elementary than most of the existing small books on the subject, and is therefore, it is believed, better adapted to the classes of students mentioned. It takes nothing for granted except an elementary knowledge of General Chemistry. Special care has been taken in selecting for treatment such compounds as will best serve to make clear the fundamental principles. General relations as illustrated by special cases are discussed rather more fully than is customary in books of the same size; and, on the other hand, the number of compounds taken up is smaller than usual, though all which are of real importance to the beginner are treated of with some degree of fulness. Thus there is less danger of confusion than when a larger number is brought to the attention of the student. The author has endeavored to avoid dogmatism, and to lead the student, through a careful study of the facts, to see for himself the reasons for adopting the prevalent views in regard to the structure of the compounds of carbon. Whenever a new formula is presented, the reasons for using

it are given so that it may afterward be used intelligently. Full directions are given for making a number of typical compounds, by methods quite within the reach of every chemical laboratory, so that with the aid of the book a systematic course of laboratory work on carbon compounds may be carried on.

The following description of the book, which is also a noteworthy commendation of it, we quote from a review of it by **Prof. M. M. Pattison Muir**, Cambridge University, Eng., published in *Nature*, London, June 4, 1885.

"This is chemistry. Of how few books professing to be books on chemistry can it be said that they teach us anything of the science! The student who begins with the study of the carbon compounds has to suffer many things from the text-books. Some of them present him with dry bones in the shape of isolated facts, and bold assertions regarding structural formulæ and the linking of atoms. Others lead him into speculations which he is unprepared to follow; he makes little flights into these, and comes back fancying he is a chemist. Other books (there are not many of them) proceed on the true scientific lines; but very frequently their pages are encumbered with too many facts about more or less widely separated compounds, or they deal so much with groups of compounds, rather than with the typical individual bodies, that the beginner soon loses his way, becomes perplexed, and is ready to abandon the pursuit.

"Prof. Remsen has shown us a more excellent way than any of these. He leads the learner by degrees through the early difficulties; he places before him distinct and detailed accounts of a few typical compounds; he shows him how these compounds are mutually related; and then he takes him back to the beginning again, and teaches him how each compound he has learned to know represents a group, and how, when he knows the properties of one member of the group, he also knows much about all the members.

"At the outset Prof. Remsen makes a few wise and pregnant remarks on the meaning of the structural formulæ. These 'enable the chemist who *understands* the language in which they are written to see relations which might easily escape his attention without their aid. In order to *understand* them, however, the student must have a knowledge of the reactions upon which they are based; and he is warned not to accept any chemical formula unless he can see the reasons for accepting it.' The whole book is a practical sermon on this text.

"In no other elementary book in the English language will the student find so many admirably chosen examples of the formation of structural formulæ. The important facts are noted; then the inference is drawn; then the hypothesis is ventured upon; analogous facts are recalled; the hypothesis is strengthened or weakened; suggestions are made; experiments are conducted; and all is finally summarized in the formula. But the book is more than a selection of examples showing how structural formulæ ought to be gained. It is a systematic although elementary treatise on organic chemistry. The student is first taught about the two paraffins, methane and ethane; then he learns how the halogen derivatives of these are prepared, and what relations they bear to the parent hydrocarbons. By this time he has had his first taste of isomerism. Then he proceeds to the oxygen derivatives of methane and ethane; he learns what an alcohol is; he becomes acquainted with ether, aldehyde, formic, and acetic acids, some ethereal salts, and acetone. This method of studying a few simple compounds in detail is pursued until the student is more or less familiar with representatives of all the principal groups of compounds derived from the paraffins. He is now in a position to study these hydrocarbons as a group, and to deal in some detail with the questions of isomerism. When the paraffins and their derivatives have been thus studied, the more difficult subject of the benzenes and their compounds is approached. And here the author shows an admirable power of dealing with facts as facts, and with theories as theories.

"Many admirable illustrations of the scientific method of inquiry are to be found throughout the book. I would especially draw attention to the simple but thorough-going treatment of the 'equivalency of the hydrogen atoms' in the molecule CH_4 (pp. 28, 29) and in the molecule C_6H_6 (pp. 234–236). It is on subjects such as are discussed in the pages referred to that the chemical student so frequently suffers shipwreck. If he will use this little book by Prof. Remsen as his pilot, and will keep a good lookout as he proceeds, he may hope to pass the shoals of the hexagon-formula and the shallows of the ortho-, meta-, and para-derivatives of benzene.

"The author of this book deserves the thanks of all chemical teachers who have tried to teach organic chemistry to beginners for the clear and short directions which he gives for preparing the important compounds of carbon. The book may well be used as a laboratory guide no less than an introduction to the science of organic chemistry."

The Elements of Inorganic Chemistry:

Descriptive and Qualitative. A Text-Book for Beginners, based on Experimental and Inductive Methods. By JAS. H. SHEPARD, Instructor in Chemistry, Ypsilanti High School, Mich. 5¼ by 7½ inches. xx + 377 pages. Cloth. Price by mail, $1.25. Introduction price, $1.12.

IT is a practical embodiment of **the modern spirit of investigation.** It places the student in the position of an investigator, and calls into play mental faculties that are too often wholly neglected. It leads him *to observe*, *to experiment*, *to think*, *to originate.* Coming as it does from the working laboratory of a practical instructor, who has had the constant advice of fellow-teachers in all parts of the country, this text may be fairly taken as an exponent of the latest methods of teaching chemistry.

Its distinctive features are: experimental and inductive methods; the union of descriptive and qualitative chemistry, thus allowing these kindred branches to supplement and illustrate each other; a practical course of laboratory work, illustrating the general principles of the science and their application; a fair presentation of chemical theories, and a conciseness which confines the work to the required limits.

Each element and compound is treated in the following natural manner: —

1. *Its occurrence*, in which the student learns where he may find it.
2. *Its preparation*, or how he may obtain it for examination.
3. *Its properties* and *uses.*
4. *Its tests*, or how he may detect its presence in known or in unknown substances.

Many equations are given to illustrate the chemical reactions in the different operations, and there are also special directions for detecting the acids as well as for separating the metals into groups, and isolating the individuals from each group.

The work closes with full and explicit directions for successfully and economically equipping the laboratory, and preparing the needed reagents and solutions.

Teachers who are compelled to compress their work into a few weeks' course can adopt the "Briefer Course" outlined in the preface, and have meanwhile the benefit of a book sufficiently complete to cover any want likely to arise in the laboratory. But average pupils of sixteen years can do all the work laid down in this text. A fair class can do the

whole work up to the metals in twenty weeks, and all the work given in metals in eight or ten weeks.

We confidently recommend Shepard's Chemistry to any teacher who now uses, or who wishes to adopt, the laboratory method of instruction.

Among its many new and valuable features, a prominent teacher specifies the following: —

1. Its *excellent methods*, which bring out the great educational force of the science, and yield exceptionally large practical results.

2. The *logical arrangement* of its subject-matter, introducing the principles of the science by easy steps.

3. Its *conciseness* and its *completeness* fully covering the beginner's wants in the working laboratory.

4. Its *mechanical excellence*, the typography being open and attractive, and the large type allowing the text to be read at a distance without injury to the eyes; the binding being such that the book will stay open on the desk while the student is at work, and the color of the cloth being such as is least affected by acids.

5. *The Appendix*, which gives (1) Instructions for equipping the laboratory; (2) Directions for preparing all needed reagents; (3) A complete list of working materials; (4) The impurities found in commercial reagents; (5) All the names by which reagents are known.

The book is based upon plans and methods which have been employed in the author's laboratory throughout a series of years, and no work has been incorporated in the text or in the exercises that has not there been proven practicable.

A wide correspondence with the best teachers in all parts of the country shows that they are pursuing essentially the same plan. Throughout the book the aim is to make the labors of the teacher as light as possible, and to "place the laboratory work where it will do the most good in the hands of the students."

"This work and Remsen's Organic Chemistry (page 1 of this catalogue) form an admirable course for the presentation to the student of the facts of inorganic and organic chemistry." — CURTIS C. HOWARD, *Prof. of Chemistry, Starling Med. Coll., Columbus, O.*

☞ A Circular, suggesting various plans of shortening the course, as well as a Special Circular, of interest to chemists and teachers of chemistry, will be sent on application to the publishers.

The Laboratory Note-Book.

For Students using any Chemistry. 4¾ by 7¼ inches. Board covers. Cloth back. 192 pp. Price by mail, 40 cts.; Introduction price, 35 cts.

IT contains blanks for experiments; blank tables for the reactions of the different metallic salts; pages for miscellaneous matter; and an extra chart for the natural classification of the elements similar to that on page 221 of Shepard's Chemistry. This may be rolled into a cylinder by the student.

The advantages of using this note-book are, briefly, these: It saves time for the student; its size is convenient; and it is cheaper than an ordinary blank-book. The paper is such that it readily takes ink without blotting or smearing, and it may be used with a lead pencil.

The value of systematic note-taking by the student in chemistry can hardly be over-estimated. The careful analyst habitually keeps record of his work, and thus the greater portion of our most valuable chemical literature has originated. If the expert finds his notes to be of inestimable value to him, what shall we say in the case of the beginner? Evidently, that he should form, at the very outset, those habits which will tend to make him accurate, and which will insure his after-success.

In the note-book the teacher has a most potent ally; for, through its aid, he may know just how his students are doing their work, and can therefore better adapt his teaching to their needs.

Our Special Circular contains fac-similes of three pages, prepared by the students in the Ypsilanti high school for 1885–6, showing how the book is to be used.

Robt. B. Warder, *Prof. of Chemistry, Purdue Univ., Lafayette, Ind.:* It strikes me very favorably. I think further examination may lead me to introduce it in Purdue University next fall. (*Apr.* 24, '86.)

F. J. Roche, *Prof. of Chemistry, University Coll., Toronto, Ont.:* I have been struck with the excellence of the second part as a means of tabulating results of simple qualitative analysis, — something most students sadly need. (*May* 15, 1886.)

Chas. W. Hargitt, *Prof. of Natural Science, Moore's Hill Coll., Ind.:* I like the plan very well for the purpose intended. (*April* 24, 1886.)

A. Wanner, *Prin. of York High School, Pa.:* Laboratory Notes in the hands of students will encourage *systematic* experiment. It is a good book for beginners, who have not the experience yet to enable them to judiciously use a blank-book. It not only will lead to frequent reference to the chemistry used, but will cultivate a habit of *accurately, clearly,* and *briefly* recording known conditions. (*March* 1, 1886.)

First Book in Geology.

By N. S. SHALER, Professor of Paleontology, Harvard University. 5¼ by 7½ inches. Cloth. xvii + 255 pages, with 130 figures in the text. 74 pages additional in Teacher's Edition. Price by mail, $1.10; Introduction, $1.00.

THE design of this book is to give the student from ten to fifteen years of age a few, clear, well-selected facts that may serve as a key to the knowledge of the earth. The number of facts dealt with is far less than is usually given in such books, but pains is taken in their presentations to make them open the way to the broadest veins that the science affords. The aim is to illustrate the principles of geology by reference to as many facts of familiar experience as possible.

The first part of the book treats of the simpler phenomena of a physical sort, the movements of the water and the air, and their effect on the machinery of the earth's surface; then the simpler underground actions are taken up, such as the formation of veins, the folding of mountains, and the forces that lead to earthquakes and volcanoes. The latter half of the book is given to the history, in outline, of the earth's organic life. This is treated in a very general way, in order to show the student only the great steps of advance, and the method in which they are accomplished.

In the appendix is a brief account of certain more important mineral species, arranged to give the student an outline of mineralogy, and some idea of the common uses of minerals.

The Teacher's Edition contains seventy-four pages of directions for those who use the book in class instruction. First there are general directions for the guidance of teachers in their work in natural history, then each chapter of the book is taken up in turn, and the instructor is told how to supplement each lesson, by reference to facts that may be easily accessible in the nature about the school.

The instructor who will make proper use of these pages will always find it possible to enliven the printed page with many an illustration of value to his students. And the average reader who desires to get a glance at geology and a general notion of its bearings on ordinary life, will find this edition of exceeding interest. It is being used in many schools as a Supplementary Reader, and is admirably adapted for such purpose.

Illustrations of Geology and Geography.

For Use in Schools and Families. By N. S. SHALER, Professor of Palæontology, assisted by WM. M. DAVIS, Assistant Professor of Physical Geography, and T. W. HARRIS, Assistant in Botany, in Harvard University.

CONSISTING of twenty large photographs and an equal number of colored plaster models. The photographs are separately mounted on suitable light frames, 15 x 20 inches in size. They represent a wide range of terrestrial phenomena, seashores, valleys, glaciers, mountains, volcanoes, caverns, etc. Alongside of each photograph is a detailed description of the important points illustrated in the picture, with occasional small diagrams, designed to show the detailed structure of the field; also references to the features in the models, which serve to explain the facts shown in the view.

The models, which are colored, are each 7 x 5 inches, and about 2 inches thick. One series shows the principal features of horizontal, tilted, and folded stratified rocks, and the varied effects of river and ocean erosion upon them; others exhibit the process of development of a volcano, of coral islands, of ocean shores, glaciers, etc. These models are separately mounted on wooden backs, to which are appended descriptions of the structures indicated, with reference to the photographs.

In the text appended to both models and photographs, there are abundant references to several text-books, where further information may be obtained. They are large enough to be seen, when in the instructor's hand, by a class of thirty students. They are designed to hang on the wall, and may, when necessary, be passed from hand to hand without injury.

The price of the full collection of fifty pieces, securely boxed for transportation, is one hundred dollars. A smaller set, containing ten models and ten photographs, will be sold at fifty dollars. When desired, the collection will be divided, and the models or photographs sold separately; the price for each set of twenty-five pieces will be fifty dollars. Specimen copies of the models and photographs, one of each, to show the nature of the method, will be sent by express, carriage paid, on receipt of four dollars, which will be returned on the receipt of the objects in good order, or accounted for if the collection is taken. A circular containing a detailed list of the models and photographs will be sent on application. [*Ready Aug.* 1.

Guides for Science Teaching.

Published under the auspices of the **Boston Society of Natural History.**

INTENDED for the use of teachers who desire to practically instruct their classes in Natural History, and designed to supply such information as they need in teaching and are not likely to get from any other source.

These *Guides* were prepared solely as aids to teachers, — not as text-books. The plan of teaching followed throughout is based upon the assumption that, —

Seeing is the first step on the road to knowledge; that, —

HOW MUCH *the child learns in his early years is of little importance*, — HOW *he learns*, *everything*; that, —

The teacher's work is not to teach the facts, but to lead the mind of each pupil to work out for itself the simple physical problems witnessed or described, and to cultivate the habit of observation and of perseverance in investigation.

The Series at present consist of the following numbers: —

About Pebbles. (*No. I.*)

By ALPHEUS HYATT, Professor of Zoölogy and Paleontology in the Massachusetts Institute of Technology. 4¼ by 6 inches. Paper. 26 pages. Introduction price, 10 cents.

This pamphlet is an illustration of the way in which a few common objects may be used to cultivate the powers of observation, and to teach interesting lessons in elementary natural science. It contains all the suggestions necessary to enable any teacher to make the lesson, or lessons, a complete success.

Concerning a Few Common Plants. (*No. II.*)

By GEORGE LINCOLN GOODALE, Professor of Botany in Harvard University. 4¼ by 6 inches. Paper. 61 pages. Introduction price, 10 cents.

The design of these lessons is to point out one method by which a few of the more important and easily observed facts can be taught respecting the structure, growth, and work of plants. The purpose of this *Guide* is to call attention to the manner of preparing the

objects selected for such elementary study, and to furnish suggestions as to the way they can most readily be turned to good account. The appliances recommended are of the most trifling cost. Even simple lenses are not absolutely required for any of the studies suggested.

Commercial and Other Sponges. (*No. III.*)

By Professor ALPHEUS HYATT. *Illustrated by 7 plates.* 4¼ by 6 inches. Paper. 43 pages. Introduction price, 20 cents.

This little manual gives an account of the sponges in common use, and amply illustrates their processes of growth, and the methods of obtaining them and preparing them for the trade. The skeletons are present to the eye every day, and even the dullest scholar will undertake with interest to find out their different qualities, their common names, where they come from, and how they are formed.

A Set of Eight Specimens has been prepared for the use of classes taking these lessons, and will be furnished for $1.00.

A First Lesson in Natural History. (*No. IV.*)

By Mrs. ELIZABETH AGASSIZ. *Illustrated by woodcuts and 4 plates.* 4¼ by 6 inches. Paper. 64 pages. Introduction price, 25 cents.

A general history of hydroids, corals, and echinoderms, written in narrative form, for very young children, under the direction of Prof. Louis Agassiz. Amply illustrated.

While scientifically accurate and clear, it is as simple and fascinating as a wonder story. No fairies could more completely win the interest of children than do sea-anemones, corals, jelly-fishes, starfishes, and sea-urchins, as described and represented in this little book.

A Set of Twenty-four Specimens, to accompany *Guides* IV. and V., will be furnished for $2.00.

Common Hydroids, Corals, and Echinoderms. (*No. V.*)

By ALPHEUS HYATT. *Amply illustrated.* 4¼ by 6 inches. Paper. 32 pages. Introduction price, 20 cents.

This pamphlet shows how the studies, or observations, are to be most satisfactorily made, and supplies such information as one nee

in teaching, and is not likely to get from any other source. The illustrations are remarkably clear and suggestive; but, to teach the pupil the value of personal observation and a correct habit of study, nothing can take the place of specimens. It is desirable that those who are to use this *Guide* shall be able to refer to No. IV. of this series, which is frequently quoted.

A Set of Twenty-four Specimens, to accompany *Guides* IV. and V., will be furnished for $2.00.

Mollusca. Oyster, Clam, and Other Common Mollusks. (*No. VI.*)

By ALPHEUS HYATT. *Illustrated with 17 plates, containing 53 figures.* 4¼ by 6 inches. Paper. 65 pages. Introduction price, 25 cents.

This book not only holds in compact form all that need be taught beginners about the oyster, clam, and other common mollusks, but is invaluable as illustrating in detail the natural method of teaching. From first to last, the pupil is a discoverer; the teacher is simply the guide, — the pupil is self-taught. The author condescends to the simplest things, and tells in the plainest way just how to lead the class to make, in proper order, the necessary investigations and discoveries. The most inexperienced teacher will be able, with this manual, to give these lessons with success.

A Set of Seventeen Specimens to be used in giving the lessons outlined in *Guide* No. VI. will be furnished for $1.00.

Worms and Crustacea. (*No. VII.*)

By ALPHEUS HYATT. *Illustrated.* 4¼ by 6 inches. Paper. 68 pages. Introduction price, 25 cents.

The space given to the description of the lobster (and fresh-water crayfish) will, it is hoped, incite teachers to occupy more time in dealing with some one common animal, and thus cultivating the habit of close observation. The specimens needed for the lessons upon worms are the common earthworms and the Neresis. In these lessons, as in the preceding, the children are to be discoverers, not mere learners, — they are to be taught by experience the value and the pleasure of direct personal observation.

A Set of Fifteen Specimens, to be used in connection with *Guide* VII., will be furnished for $1.00.

Orders for Specimens to accompany Guides III., IV., V., VI., or VII., should be addressed to SAMUEL HENSHAW, *Boston Society of Natural History, Boston, Mass.*

Larger collections, and sets for students' use, containing ten, twenty, forty, and sixty specimens of a single form, can be obtained by special arrangement with Mr. Henshaw.

Common Minerals and Rocks. (*No. XII.*)

By W. O. CROSBY, Assistant Professor of Mineralogy and Lithology in the Massachusetts Institute of Technology. *Illustrated.* 4¼ by 6 inches. Paper. 200 pages. Introduction price, 40 cents. Cloth, 60 cents.

This includes, first, a brief and simple account of the principal geological agencies; second, descriptions of about twenty minerals of which rocks are chiefly composed, and of all the more common and important varieties of rocks; and, third, an explanation of the leading kinds of structure occurring in rocks, such as stratification, folds, faults, joints, etc. This last section of the *Guide* is illustrated by forty figures, which add very materially to the clearness and value of the text.

Especial prominence is given to the easy identification of the common minerals and rocks, and to the constant association, in the mind, of the rocks and rock-structures with the agencies by which they have been formed.

This little volume is not merely a guide to teachers, but it is also a simple and logical presentation of the leading facts and principles of structural geology, and is well adapted for class use. It is hoped, however, that teachers will base their instruction upon specimens of minerals and rocks, using this work more as a reference book than as a text-book, in the hands of pupils. Natural science cannot be successfully taught with books alone; and even the best books should supplement, but not precede or take the place of, actual observation.

Specimens to illustrate Guide No. XII., comprising the twenty principal elements and minerals, are supplied in durable, covered boxes, properly labelled, as follows: —

1 large specimen of each kind,				20 in all, labelled		. . .	$ .50
5 smaller specimens of each kind,				100	" "	. . .	1.25
10	"	"	" "	200	" "	. . .	2.25
20	"	"	" "	400	" "	. . .	4.00

Ten additional varieties are supplied in the same way: —

1 large specimen of each kind,	10 in all, labelled	. . .	$ .30
5 smaller specimens of each kind,	50 " "	. . .	.75
10 " " " "	100 " "	. . .	1.50
20 " " " "	200 " "	. . .	2.50

Orders for these specimens should be addressed to Prof. W. O. Crosby, *Boston Society of Natural History, Boston, Mass.*

First Lessons in Minerals. (*No. XIII.*)

By Ellen H. Richards, Instructor in Mineralogy, Massachusetts Institute of Technology. 4¼ by 6 inches. Paper. 50 pages. Introduction price, 10 cents. A valuable introduction to *Guide* No. XII.

The outline of the lessons was first worked out with three successive classes of children, from six to eight years old, just out of the Kindergarten. The lessons were then given to classes in two public schools in the city of Boston. During the two years which have since elapsed, they have been given to about one thousand children of the fourth classes of several of the Boston Grammar Schools. They have also been adopted by teachers in other places. Such changes have been made as experience has shown to be desirable, and the *Guide* is now presented in a form which can be recommended to teachers in general.

The specimens to illustrate Guide No. XIII. consist of large, carefully selected cabinet specimens, with printed labels. It is desirable, however, to have a specimen of each type for every pupil, or at least for every two or three pupils. To meet this need, duplicate collections of somewhat smaller specimens, numbered but not labelled, have been prepared.

	50 specs.	80 specs.	125 specs.	150 specs.
Cabinet size,	$2.00	$4.00	$8.00	$10.00
Student size, 2–5 colls.	1.00 ea.	2.00 ea.	4.00 ea.	5.00 ea.
" " 6–10 "	.90 ea.	1.80 ea.	3.60 ea.	4.50 ea.

The student collections are not sold singly.

Other collections, adapted to more extended courses, are supplied as follows: —

Minerals.	50 specs.	100 specs.	150 specs.
Cabinet size,	$6.00	$15.00	$30 00
Student size,	2.00	5.00	10.00

W. K. Brooks, *Director of the Chesapeake Zoölogical Laboratory, Johns Hopkins Univ.*: I have examined the Ms. of your proposed book on zoölogy, for use in schools, and I am glad that the author has undertaken to make his experience in teaching natural science available for other teachers, who have not had the special training in this branch of science which he has enjoyed. I am sure that the book will meet with a ready sale, and will be very useful to teachers. (*Dec.*, 1885.)

S. A. Forbes, *Prof. of Zoölogy, Univ. of Illinois, and State Entomologist*: It seems to be in every way skilfully prepared, and cannot but be both useful and successful. This is just such a piece of work as has long been needed in public schools.

Newton Bateman, *President Knox Coll., Galesburg, Ill.* (*formerly Supt. of Public Instr. of the State of Ill.*) : If you are able to develop the whole subject with the clearness and charm of these specimen chapters, the result will be a very useful and fascinating book. It will train the faculties of observation to alertness and accuracy. It will bring that deep satisfaction which comes only from original work; from getting first-hand knowledge. It will vitalize the half-dead facts of mere book and memory by the quickening and realistic power of the eye and the hand, directed by keen curiosity and the wide-awake mind. The book is needed. It will be welcomed and appreciated.

Henry Raab, *State Supt. of Public Instruc., Springfield, Ill.*: This is a work that presents, for the first time, a guide for the teacher, by means of which he may introduce the pupils to the science successfully, *i.e.*, that they may *like* the study of nature, may prepare for more advanced science work, and gain a lasting benefit for their intellectual development. I shall commend it to teachers of science in our public schools whenever I have an opportunity.

L. M. Underwood, *Instructor in Zoölogy, Syracuse Univ., N.Y.*: I am more and more pleased with it as it proceeds. I expect to make use of the book in my classes next fall. (*June* 26, 1886.)

M. L. Seymour, *Prof. of Zoölogy, Ill. Normal Univ.*: I have no criticisms. I find the plan, directions, description, and wording excellent. I want to use the book in my classes as soon as published.

J. H. Pillsbury, *Biological Laboratory, Smith Coll., Northampton, Mass.*: The plan seems to me to be a very good one for the work for which the author has intended it. I am glad to see so good a plan offered for our high schools. If the remainder of the work is equally good, it ought to be a success. (*March* 19, 1886.)

E. P. Jackson, *Teacher of Zoölogy, Boston Latin School*: I think the pages I have examined excellent. All enlightened teachers are aiming at the very standard *in general* which these pages reach *in particular*. If I had a book in my class constructed on precisely this model, I should use it with great confidence and zeal. (*Nov.* 10, 1885.)

O. S. Westcott, *Prin. N. Div. High School, Chicago, Ill.*: The book is attractive. I think it would sell with thoughtful teachers.

J. Y. Bergen, Jr., *Prin. of High School, Peabody, Mass.*: I have gone over the manuscript with care, and feel satisfied that there is no American book on zoölogy adapted for use with high-school classes which will enable them to learn so much *at first hand* as they can from this book. It does for the pupil what without it the conscientious teacher must otherwise do for him by constant and laborious reference to the fuller works. (*Jan.* 3, 1886.)

How to Find the Stars.

By Rev. James Freeman Clarke. 4¼ by 5½ inches. Paper. 47 pages. Introduction price, 15 cents.

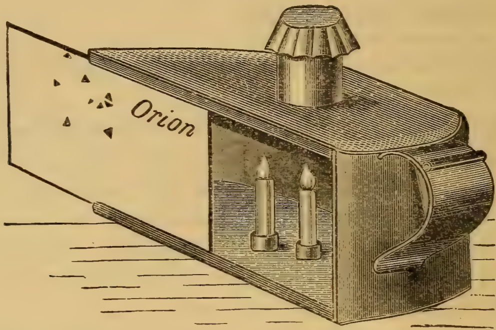
THE object of this little book is to help the beginner to become better acquainted, in the easiest way, with the visible starry heavens; to know the winter and summer constellations, and the principal fixed stars. It shows the position of the constellations at different periods of the year, giving their place in each of the four seasons. It also shows how to find the separate clusters by a series of triangles and diagrams, covering the whole heavens, and connecting each constellation with its neighbors. It indicates the most interesting objects at each period of the year, especially such as can be found with a telescope of moderate power. It closes with a description of the Astronomical Lantern.

An Astronomical Lantern.

Invented by Rev. James Freeman Clarke, Boston. Japanned tin; the face (6½ by 10 inches in size) is of ground glass, behind which lights may be placed. Thirty-two constellations are photographed upon seventeen slides of semi-transparent card-board, and stars of four magnitudes are represented by perforations of proper size. The maps have been prepared under Dr. Clarke's personal supervision, and the plates, being photographed from the original drawings, are correct in every particular. The former price of the Lantern was $6.00; we now offer it, in improved form, with the slides, and a copy of "How to Find the Stars," for $4.50. The whole carefully packed in a wooden box, with sliding cover.

THE object of this useful piece of apparatus is to facilitate the study of stellar astronomy. It is intended for beginners in astronomy in schools and in families, and, in fact, for all who desire to become acquainted with the constellations.

The difficulty hitherto experienced in this study, and which is obviated by the use of the lantern, is this: In order to study the starry heavens, it has been necessary to use an astronomical atlas or a celestial globe. These must be examined in the house, by the light of a lamp. The observer, having found his constellation on the atlas, goes out to look for it in the sky. But by the time he gets out of doors, he has forgotten how it looked on the atlas. And when he has found it in the sky, he forgets how it looked there, before he gets back to his atlas or globe.



Now, the astronomical lantern makes the study of the stars perfectly simple and easy. It is constructed like a dark-lantern, closed on three sides, and on the fourth provided with a ground glass, in front of which maps can be inserted. On each of these maps, which are semi-transparent, is represented a constellation, the places of the stars being indicated by perforations, through which the light shines. The largest perforations are for the stars of the first magnitude, and the smaller, in due proportion, for the lesser stars. The student, therefore, wishing to observe any particular constellation or cluster, has only to light a candle within the lantern, insert the appropriate slide, and go out into the night. Holding up the lantern in one hand, he can compare the constellation as it appears on the lantern with that in the sky, until he becomes perfectly familiar with the latter.

It is easy to see how much the use of such a lantern facilitates the whole study. In fact, we think that henceforth no one wishing to become acquainted with the heavens can afford to dispense with it. The increased ease of the study should also enlarge the number of students in this interesting department of science.

The following testimonials as to its value have been recently received:—

C. A. Young, *Prof. of Astronomy, Princeton Coll.:* I find it to be an admirably contrived apparatus for its purpose, — simple, easily managed, and effective. I think an adequate knowledge of the constellations could be obtained by its use, in connection with the little book that accompanies it, more rapidly and easily than from the most elaborate and expensive celestial globe. (*Aug.* 8, 1885.)

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